Capacity Max System Planner

MN002732A01–AA

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Part I

System Description

This section describes the Capacity Max System features.

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Chapter 1

Capacity Max System

This chapter describes a Capacity Max system.

Overview

Capacity Max is a MOTOTRBO's control channel based trunked radio system. MOTOTRBO is Motorola's digital radio products marketed primarily to business / industrial users. It uses ETSI's DMR standard (2-slot Time Division Multiple Access (TDMA)) to pack two simultaneous voice or data in a 12.5 kHz channel (6.25 kHz equivalent).

MOTOTRBO offers multiple radio systems, which are IP Site Connect, Capacity Plus, Connect Plus, and Capacity Max. Except for IP Site Connect (a Conventional multi-site system), the rest are trunked systems. A trunked system allows the radios to share the channels. It allows a large number of talk groups to communicate over few channels and effectively increases the utilization of channels.

The trunking in Capacity Plus uses the rest channel instead of the control channel. In a control channel based system, the idle radios wait on the current control channel, but in a rest channel based system, a call starts at the rest channel, and the non-participating radios move to the next rest channel.

The Connect Plus and Capacity Max, are control channel based system. The main difference between them is, the Capacity Max is based on the European Telecommunications Standards Institute's (ETSI) Digital Mobile Radio (DMR) trunking protocol, while the Connect Plus follows a proprietary trunking protocol.

Trunking Methods of DMR

Capacity Max supports all the trunking methods of DMR. It supports "transmission trunking", "quasi-transmission trunking", and "message trunking". There are no explicit configurations for these trunking methods. They are achieved by configuring suitable values for the Call Hang Time. Table 1 explains the trunking methods and its Call Hang Time.

Table 1: Trunking Methods and the Call Hang Time

Trunking Methods	Definition	Advantages and Disadvantages	Configuration
Transmission	A trunked channel is allocated on start of every transmission of a call. At the end of a transmission (for example, release of the PTT), the trunked channel is de-allocated and all the participating radios return to the control channel. The next transmission is allocated a new trunked channel.	Users experience a delay for each transmission particularly when the system is busy, when no trunked channel is available. The call processing capacity of a site is less (Control channel is used for starting every transmission). The trunked channel utilization is high, as trunked channels are allocated only during transmissions.	Call Hang Time = 0
Quasi-transmission	A trunked channel is allocated for the duration of the call. At the end of a	This method overcomes the delay of Transmission trunking except for the first transmission.	Suggested Call Hang

Table continued…

	transmission (for example , release of the PTT), the channel remains allocated for a short Call Hang Time to permit the radio users to speak. If the Call Hang Time expires, the trunked channel is de-allocated and the call ends.	The call processing capacity of a site is good. Control channel is used for starting only the first transmission. The trunked channel utilization is less (Trunked channels are allocated also during Call Hang Times).	Time = 2 to 6 seconds
Message	A trunked channel is allocated for the duration of the call. The trunked channel is de-allocated when the call is explicitly cleared by the call initiator (during a talkgroup call), by either party hanging up (during an individual call), or on expiry of a large Call Hang Time.	The delay in starting of a transmission and call processing capacity are same as that of Quasi-transmission. The disadvantage is that the channel remains allocated even when there is significant time gaps between the transmissions. This results in less efficient use of the trunked channels.	Suggested Call Hang Time = 20 to 30 seconds

Modes of Operation

Capacity Max increases the capacity (for example, the number of calls per unit of time) of a radio system beyond what is supported by the DMR trunking protocol. To achieve this, the Capacity Max infrastructure offers the following two modes:

1. Open System Mode — This mode uses DMR trunking protocol and therefore it supports both MOTOTRBO and non-MOTOTRBO radios. In this mode, a Capacity Max system provides more capacity when it is working with the MOTOTRBO radios. Some of the methods used for capacity enhancements are:
    - Registration on second slot: A MOTOTRBO radio uses the second slot of the control channel for registration and authentication, if the second slot of the control channel is not in a call. A Capacity Max system allocates a call to the second slot of the control channel only if no idle channels are available. This frees both inbound and outbound of the control channel for initiation of other services.

      NOTICE: The control channel of a Capacity Max system is always on the first slot.
    - Arbitration during a call: During a call hang time, radios at different sites may try to initiate their transmission almost at the same time. The system needs to arbitrate among them. MOTOTRBO radios on a Capacity Max system do the arbitration over the trunked channels. This frees the control channel.
2. Advantage Mode — This mode provides more capacity than the Open System Mode. All the capacity enhancements of Open System Mode with MOTOTRBO radios are also available in Advantage Mode.

It achieves higher capacity by compressing the announcement of ongoing calls over the outbound of the control channel.

NOTICE: The outbound control channel becomes the dominant factor in restricting the capacity, when more and more calls are multi-site calls.

Advantage Mode uses proprietary protocol over the air and therefore it does not support non-MOTOTRBO radios. Some of the features (for example, faster “late entry” to an ongoing call), which use proprietary messages over the air are only available in this mode.

Other than Open System Mode and Advantage Mode, a Capacity Max radio has a third mode (Open Radio Mode), which is used by the radio when it is working in a Non-Motorola DMR Tier III system. In this Open Radio Mode, a radio does not use any proprietary features.

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Chapter 2

Capacity Max Control Channel

This chapter describes about the control channel in a Capacity Max system.

Capacity Max’s control channel is based on the **DMR trunking protocol**. The **DMR trunking protocol** requires at least one logical channel to be assigned as a control channel. The control channel has an inbound communication path for transmissions from radios, known as the inbound control channel. A radio randomly accesses the inbound control channel to request access to the system. The required resources (for example, channels) are then allocated by the system. The system informs the radios of the allocated resources an outbound communication path, known as the outbound control channel. All the radios that are not participating in a call listen to the outbound control channel. The allocated resources are released and can be subsequently allocated to other requests. This method of sharing channels is known as trunking, and the channels are referred to as trunked channels.

Dedicated Control Channel

The Capacity Max system transmits continuously over a dedicated control channel. One dedicated control channel can support a large number of trunked channels. This mode of operation yields the highest performance and throughput.

Opposite to a dedicated control channel is the time-shared control channel where a physical channel is shared by multiple trunk systems by dividing the use of the physical channel in time. The DMR trunking protocol does not provide mechanism to support time-shared control channels.

Capacity Max does not support composite control channel. In case of composite control channel, when required the control channel reverts to a trunked channel if no other trunked channels are available. A composite control channel is useful for a site, where only few frequency pairs are available and it degrades the throughput and performance.

Active Control Channel

The DMR Trunking protocol allows a site to operate with one or two control channels. Two control channels increases the capacity of the site, but requires the radios at the site to be sub-divided into two partitions. This allows load sharing between the two control channels.

The load sharing is not effective for calls, which require participation of radios from both the partitions. This is because the system must inform the allocated resources to radios on the outbound path of both control channels. Thus, a Capacity Max system supports one control channel at each site. To increase the capacity of its control channel, a Capacity Max system off-loads certain uses (e.g. Registration and Authentication, Arbitration during hang times) of control channels to trunked channels. To reduce configuration, the control channel of a Capacity Max system is always on the first slot of a physical channel.

Multiple Control Channels

Capacity Max allows up to four channels to be designated as the candidate control channels.

To offer radio services, a site should have at least one repeater that is a candidate control channel. Multiple candidate control channels help, when the active control channel fails. In the event of the active control channel failure, one of the remaining candidate control channels is selected as the next control channel.

Preferred Control Channel

Capacity Max allows one or more candidate control channel to be the “Preferred Control Channel”.

A non-preferred candidate control channel acts as a control channel, only if the site has no “Preferred” candidate control channel. The preferred channel having the lowest “Repeater Id” is selected as the control channel, when there are multiple preferred control channels.

The “Preferred” option is useful, when a frequency pair is more suitable (for example, less interference) as the control channel over other candidate control channels.

Control Channel Rotation

A MOTOTRBO repeater is capable of performing the role of a control channel continuously without increasing its failure rate (for example, failure of power amplifier). Thus, the Capacity Max system does not move the control channel periodically.

In a Capacity Max system, the control channel moves from repeater A to repeater B, only if:

- Repeater A fails and there is no hardware redundancy; or
- Both repeater A and its redundant repeater fail; or
- Repeater A is not the preferred control channel repeater, and repeater B which is the preferred control channel repeater, powers on or has recovered from a failure.

Chapter 3

Capacity Max Voice and Data Services Over Trunked Channels

This chapter describes calls initiated over the air on a control channel and describes the life cycle of a call, including call initiation, call queuing, call grant or rejection, call transmissions, and call termination. This chapter focuses on the parts of the life cycle that apply to multiple call types.

Overview

Call processing is the primary function of Capacity Max and any other radio system. A call is initiated either over the air (that is, by a radio) or over the wire (that is, by a device such as a voice or data gateway). In Capacity Max, a call is initiated over the air either on the control channel or on the revert channels. This section describes only calls initiated over the air on a control channel. A Capacity Max system supports multiple types of calls. This section focuses on the parts of the life cycle that apply to multiple call types.

Channel Acquisition and Registration

Before initiating a service at a site, a radio must acquire the control channel of the site, and be successfully registered at the site (except when the site is in Site Trunking mode).

A radio registers with the system:

- On power-on
- On roaming to a site
- On changing the personality (that is knob position) from another system to the Capacity Max system
- On changing personality (that is knob position) having a different Tx talkgroup
- When the radio has not received a response for its request within the number of hours configured as the Inactivity Check time

Successful registration requires the following conditions:

- Subscriber Access Control (SAC) should have an entry for the radio.
- The radio should not be disabled in the SAC.
- The site should be in the list of the Valid Sites of the radio in the SAC.
- Authentication is required by the system with the following conditions:
  - The radio has the right key.
  - The SAC has the radio’s physical serial number (PSN) (For MOTOTRBO radio only).
- The radio is in the coverage area of the control channel of the site, that is, the radio is receiving the outbound transmission over the control channel.
- The color code and the SYScode in the outbound transmission match those configured in the radio.

An unregistered radio does not unmute to a voice or data call.

Initiation of Request for Services

A radio initiates all requests for services over a control channel by randomly accessing the control channel.

After acquiring a control channel and successfully registering, a radio that needs to initiate a service accesses the control channel as specified in the random access procedure defined in the DMR III standard. The main purpose of the random access procedure is to reduce collisions caused by simultaneous accesses of the control channel by multiple radios. The random access procedure also minimizes access delays and maximizes throughput under heavy traffic loads.

An attempt at random access may fail under any of the following conditions:

- The time slot, which was randomly selected by the radio for accessing the control channel, is no longer available for random access. When the infrastructure solicits a response from a radio, it transmits a packet data unit (PDU) on the outbound channel. In order to prevent a collision occurring between this solicited response and a random access transmission by another radio, the infrastructure prohibits any random access transmissions in the given timeslot.
- Another radio randomly accesses the same timeslot. Subject to the relative signal strength of the transmissions, one or both transmissions may be lost over the air.
- The radio’s signal is corrupted by noise.
- The request from the radio is received over-the-air but is lost over the wireline network in the infrastructure.

To reduce the probability of failure of random access, a Capacity Max radio makes multiple attempts with random delays in between. The maximum number of attempts for requesting emergency services is higher than the one for requesting non-emergency services. Due to multiple attempts and random delay in between them, a random access may take a long time. Capacity Max puts an upper limit (approximately ten seconds) on the duration of the random access procedure.

Radio users are not required to keep the push-to-talk (PTT) button pressed during the service request process. Momentarily pressing the PTT button is sufficient.

Qualification of Service Requests

A Capacity Max system qualifies all requests for services.

On receipt of a service request from a radio, the infrastructure verifies the source and target (if any) of the request. The source (that is, the requesting radio) must satisfy all of the following conditions:

- The requesting radio is present in the SAC.
- The requesting radio is enabled in the SAC.
- The requesting radio is registered.
- The requesting radio is permitted to be on its current site in the SAC.
- The requesting radio is permitted to initiate the requested service in the SAC.

The target and the conditions that the target must satisfy depend upon the type of the service and are described in articles on specific call types.

Service Setup Using All Start

A Capacity Max system sets up a service using “All Start” method.

A Capacity Max system starts a qualified service request only when at least one trunked channel is available at all the sites that are associated with the service at that time. This method may delay the start of a service (when trunked channels are not available at one or more associated sites), but guarantees that the all the associated sites participate in the service.

- For an individual call, the associated site(s) is/are the site(s) where the source and target radios are present.
- For a talkgroup call, the associated site(s) consist of the following:

- The sites that a system administrator has statically associated with the talkgroup by configuring in the radio management application.
- The sites where at least one radio has affiliated for the talkgroup.
- The site where the call request is being initiated.

The system checks the availability of channels only at the sites that are present in the system at that time. When a site is isolated from the rest of the system, the system does not include the site in the associated sites.

Service Request Queuing

A Capacity Max system queues the service request.

If a trunked channel is not available at an associated site, the system queues the service request and informs the source radio. Emergency voice calls and broadcast “all calls” also follow the “All Start” method. However, if a trunk channel is not available at the associated sites, a busy trunked channel (busy with anything besides an emergency or all call) is assigned to the call, and if there is no such channel, then the request is rejected.

When a trunk channel becomes available, the system checks the service requests in queue for the availability of all the required channels. If there are more than one such service requests, then the system selects one of them and allocates channels to the selected service request. The selection is based on the priority of the service request, which is the maximum of the priority of the initiating radio, and the priority of the target (a radio or a talkgroup).

A Capacity Max system allows the system owner to configure a priority for each radio and each talkgroup.

Service requests having the same priority are processed using the first-come-first-served principle.

A service request waits in the queue until all required channels become available. This has the following implications:

- Between two service requests having the same priority, the request with fewer required channels is likely to be processed first.
- During heavy usage, requests remain in the queue longer, and the radio may receive the grant after its waiting period is over. When this occurs, the service initiating radio does not initiate transmission, and the allocated channels are wasted for few seconds. A system owner can configure the duration of the wait period (that is, the TP_Timer) for which a radio waits for the grant of its queued request. Radios in a heavily loaded system should be configured with a greater TP_Timer (a system-wide parameter).

Some of the advantages of queuing in a loaded system are that it improves channel utilization, and a radio user is not required to press PTT multiple times. A disadvantage is that in a heavily loaded system, the recent requests have to wait for the older requests. Queing increases the delay in processing a request. In many scenarios, the delay is not desirable. For this reason, a Capacity Max system allows its system owner to disable or enable the queuing. When queuing is disabled, the system does not use priority of radios or talkgroups, and the TP_Timer could be small (around 4 seconds).

When channels are assigned to a talkgroup request in the queue, all queued requests for the same talkgroup and same call type (voice or data) are removed from the queue. A radio can have only one service request in the queue at any time. When the radio makes a new service request, the previous service request is removed from the queue.

Channel Allocation

A Capacity Max system allocates channels to a service request according to the system owner’s preference.

A Capacity Max system allows system owners to configure their preferences for usage of a physical trunked channel (both slots) in a repeater. The guidelines for assigning the preference level for a trunk channel are:

- Exclusively licensed channels should have higher preference than the shared channels.
- Within shared channels, the preference is inversely proportional to the co-channel user activity.

When a service request is selected for allocation of channels, the system assigns a trunk channel at a site according to the following rules.

- Within all ‘Idle’ trunk channels at that site, the high preference trunk channel is assigned before the low preference trunk channel.
- Within same preference level, trunk channels are assigned in round robin method.
- The trunk channel on the second slot of a control channel repeater is assigned only when no other idle channel is available at the site. The second slot of a control channel is used by MSI radios for registration.

Retention of Ongoing Calls

Any changes in the system data do not affect the ongoing calls.

To set up a call, a Capacity Max system uses several data sets such as the Subscriber Access Control (SAC), static associations between sites and talkgroups, and talkgroup affiliation (that is, subscription). Any change in the data sets after the allocation of channels to a call does not affect the call. For example, during a call, if the system owner disables the source or destination of the call, the call does not stop.

Late Entry to Voice Talkgroup Calls

A radio can enter a voice talkgroup call if it was not on the control channel at the time of call initiation. This condition may occur when the radio is at another site, out of coverage, in fade, transmitting over a revert channel, or participating in another call.

A Capacity Max system supports late entry for voice talkgroup call only. The probability of having late entry for an Individual call is small because an Individual call starts after acknowledgement from the target radio/user.

To facilitate late entry, a site announces periodically all the ongoing voice talkgroup calls over the control channel. The announcements are more frequent (that is, late entries are approx. 50% less late) in Advantage mode than in Open System mode of a Capacity Max system. In Advantage mode, the lateness can be further shortened by approximately 50%, if the talkgroups’ IDs are less than 1024.

For radios participating in a call over trunked channels, ongoing emergency and all calls are announced periodically over the busy trunked channels. The announcements are more frequent (that is, late entries are less late) if the emergency talkgroups IDs are less than 1024. On receiving an announcement, a radio moves to the announced call if the announced call is of interest and has higher priority than its current call.

Floor Arbitration of Trunked Channels

A call is made of multiple transmissions, where the maximum time gap between two consecutive transmissions is called call hang time. A Capacity Max system allows its system owner to configure three hang times, one each for talkgroup voice call, individual voice call, and emergency voice call.

During a call, a radio accesses the trunked channel by being polite to its own color code (that is, a radio cannot talk over other radios in a call) except in case of Voice Interrupt, and during a telephone call a radio is impolite to the phone.

The radios participating in the call stay on the trunked channel during the call hang time. A radio can initiate a transmission during the call hang time. In a call involving multiple sites, radios at different

sites can initiate voice transmissions near simultaneously. A Capacity Max system uses a floor arbitration algorithm, which selects one of the radios for transmission.

The floor arbitration algorithm is a proprietary feature and is used only by Motorola Solutions radios when they are operating in a Capacity Max system. For non-Motorola radios, some transmissions have more than one radio transmitting over each other. The probability of this increases as the number of non-Motorola radios increases.

In some trunked radio systems, radios that need to transmit during hang time move to the control channel and request permission. The system arbitrates with any other requests received from other radios for the same call and provides a grant or reject. The disadvantage is that the request for every transmission reduces the inbound capacity (that is, the number of calls initiated per hour) of the control channel. For example, if a call has on the average 2.5 transmissions and the inbound capacity is 12000 random accesses per hour, the request for every transmission reduces the capacity to 4800 calls per hour.

Call Termination

A Capacity Max system allows a radio user to terminate a call.

A call is terminated if one or more of the following conditions occur:

- A radio can initiate a “call end request” during hangtime on the trunk channel where the call is ongoing.
  - In a talkgroup call, only the call initiating radio (that is, a radio whose request for the call was granted) can initiate a call end request.
  - In an Individual call, either the source radio or the target radio can initiate a call end request. This feature improves the channel utilization, especially in case of a long call hangtime.
- The Call Hangtime has expired because no radio initiated transmission during the call hangtime.
- The Time Out Timer (TOT) of either the radio or the repeater has expired.

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Chapter 4

Capacity Max Voice Talkgroup Call

This chapter describes features that are common to processing of services, as well as features related to talkgroup calls.

Overview

In a Capacity Max system, a talkgroup can be selected in any of the following ways:

- A Capacity Max radio supports multiple personalities that can be selected using knob position. A personality has a “contact name”. A radio user can make a call to the contact name by just pressing the PTT button. If the contact names of multiple personalities of a radio are talkgroups then the radio user can select a talkgroup using the knob.
- A Capacity Max radio supports an address book. A radio user can make a call to an entry in the address book using the radio’s menu. This can be done even when the radio is receiving a call.
- A personality has a “group list”. The group list can have up to 16 talkgroups. A radio user can receive a voice or data group call, only if it is for one of the 16 talkgroups or it is for a All talkgroup, that is site-wide or multi-site.

List of Valid Sites

A Capacity Max system allows a system owner to list the sites that are valid for a talkgroup.

For a talkgroup call (including multi-site all call talkgroup), a system owner can list the sites where a call for the talkgroup can be initiated. A call for the talkgroup cannot be initiated from a site that is not in the list. In addition, a call for the talkgroup is never transmitted over the air at a site that is not in the list. By default, the list of valid sites for a talkgroup contains all sites.

This list allows a system owner to bill its customers based on the coverage area of a talkgroup.

If a radio requests registration and affiliation of its Tx talkgroup (contact name) at a site that is not in the list of valid sites for the talkgroup, the system registers the radio, but with a warning. The radio displays the warning, which may prompt the radio user to either roam manually to another site or use the knob to select a different talkgroup (if configured). The radio is not able to make a call to its Tx talkgroup (contact name), but it can do the following:

- Receive calls for its Rx talkgroups in the “group list” that are valid at the site.
- Make or receive individual voice or data calls.
- Make a call to a talkgroup (including an emergency talkgroup) that is valid at the site.

List of Static Sites

A Capacity Max system allows a system owner to list sites where a talkgroup call is always transmitted over the air.

A call for the talkgroup is always transmitted over the air at all the sites in the list of static sites even when no radios have affiliated at the site. By default, the list of static sites for a talkgroup contains no sites. All sites in the list of static sites must be in the list of valid sites for the talkgroup. In other words, the list of static sites is a subset of the list of valid sites for a talkgroup.

Affiliation of a talkgroup by a radio is an optional DMR Tier III feature, and some non-Motorola radios may not affiliate their talkgroup. In that case, the system owner can statically associate their talkgroup to the required sites.

Normally, emergency talkgroups are exclusively used for emergency purposes. No radio may affiliate for the emergency talkgroup, and the emergency call cannot be transmitted at a site where recipient radios are not present. In that case, the system owner can statically associate their talkgroup to the required sites.

Static site associations should be used judiciously because transmitting a talkgroup call at a site where no listeners are present is a waste of channel resources.

Sites with Successful Affiliation

A talkgroup call is transmitted at all sites where at least one radio has successfully affiliated to the talkgroup.

A radio affiliates to only one or zero talkgroup at a time. The radio affiliates its Tx member (contact name) only if it is a talkgroup (excluding site-wide or multi-site All talkgroups). The system rejects affiliation of any talkgroup that is not valid at the site.

Talkgroup Call Affiliation

A talkgroup call can be initiated from any valid site for the talkgroup.

Affiliation is required for receiving a call, but not for initiating a call. Thus, a radio can initiate an emergency call from a site even when no radio has affiliated the emergency talkgroup at that site.

A talkgroup call is transmitted at all the valid sites for any of the following conditions:

- The site is statically associated with the talkgroup.
- At least one radio has affiliated to this radio.
- The site is the source site.

Broadcast Talkgroup Call Configuration

A Capacity Max system allows a talkgroup to be configured as a Broadcast Talkgroup Call.

“Broadcast” is an attribute of a talkgroup call. A Capacity Max system sets this attribute to a usage (for example, a transmit member (contact name) of a personality, an entry in the address book) of a talkgroup. An address book can have two entries for a talkgroup – one with broadcast and other without broadcast.

In a broadcast talkgroup call, only the initiating radio transmits. The call has hangtime (same as a talkgroup call) but during hangtime only the call initiating radio can transmit.

Other participating radios cannot interrupt a broadcast call.

Normally, a large number of radios are members of a broadcast talkgroup. By not allowing other radios to transmit during hangtime of a broadcast call, over the air collisions of responses of the other radios can be eliminated.

Chapter 5

Capacity Max Individual Voice Call

This chapter describes the additional features related to Individual calls.

Overview

An individual call is a voice call between two entities, where both entities have non-reserved radio IDs.

In Capacity Max, other than a radio, a voice application (for example, console) has a radio ID and an individual call may be between a radio and a console.

The DMR III standard has reserved some of the IDs between $FFFECO_{16}$ and $FFFFFF_{16}$. These IDs cannot be used for a radio.

In Capacity Max, an individual call is transmitted over-the-air at one or two sites. It is transmitted at one site if the source and the target radios are at the same site, or the source or the target is a voice application.

Individual Call Types

In Capacity Max system, an individual call starts only after ensuring the availability of the destination.

Capacity Max system supports the following types of individual calls:

OACSU (Off Air Call Set Up)
An individual call is set up after checking the availability of the destination radio.

FOASCU (Full Off Air Call Set Up)
An individual call is set up after checking the availability of the user of the destination radio, and the user indicates willingness to accept the call.

FOACSU and OACSU improve the reliability of the Individual calls. Once an Individual call is set up, there is a very small probability that the target radio will not participate in the call. The advantage of FOACSU over OACSU is that the FOACSU provides additional control of accept or refuse to the user of the destination radio. The disadvantage of FOACSU is that it requires additional signaling over the control channel.

Capacity Max does not support a PATCS (Push And Talk Call Setup) individual call. A PATCS call is set up without checking the availability of the destination.

NOTICE: The destination may not be in a state, such as out of coverage or in another call, to receive the call and therefore the PATCS calls may waste channels.

Individual Call Control

A Capacity Max system allows the system administrator to control the individual call capability of a radio.

Using Subscriber Access Control (SAC), a system administrator can enable or disable a radio’s capabilities as follows, including voice application:

- To receive an individual voice call
- To initiate an individual voice call

A Capacity Max system also allows a system administrator to select between OACSU and FOACSU, and the selection is for the whole system. It is applicable to all individual voice calls except phone call. A single selection for all individual voice calls provides a consistent experience to the user.

NOTICE: As per DMR III standard, the source radio of an individual call cannot specify the call setup method in the call request.

Individual Call Initiation

A Capacity Max system allows a radio user to initiate an individual call in three ways, as follows:

Manual Dial
A radio user can manually dial the ID of the target radio. This option can be turned on or off via CPS. Manual dialing is possible only from a radio having display.

Address Book Dialing
The target radio has an entry in the address book and the radio user selects the target radio using the address book. Address book dialing is possible only from a radio having display.

One Touch Dialing
A radio user pushes a programmable button of the radio to dial a pre-programmed radio ID.

The following are some other salient features of an individual calls:

- A radio in Emergency state does not participate in an individual call.
- A stunned radio does not participate in a voice individual call.
- An individual voice call can be terminated either by the source radio or the target radio.
- A Capacity Max system allows a system administrator to configure a hang time for individual calls. The hang time is independent of the hang time for talkgroup calls.

Chapter 6

Capacity Max Voice All Call

This chapter provides additional features related to All Calls. The chapter on Capacity Max Voice and Data Services Over Trunked Channels on page 17 describes the features that are common to processing of services.

Overview

An All Calls is a broadcast voice call between a call initiating entity and all the entities present at a location where:

- An entity (for example, a radio, a voice application, or a data application) has a non-reserved radio ID. The DMR Tier III standard has reserved some radio IDs between $FFFECO_{16}$ and $FFFFFF_{16}$.
- A location could be a site, a set of sites, or all sites in a system.
- A Capacity Max system does support a voice call to all the sites, but does not support the System-wide All Call.
- A Capacity Max system does not support a data call to a site, a set of sites, or all the sites.

Like a talkgroup call, a broadcast call has a hangtime, but only the call initiator can transmit or terminate a call during that hangtime.

Voice Site-Wide and Multi-Site All Call

An All Call whose location is a site (called site-wide All Call) is received by the radios at the specified site only. For an All Call initiated by a radio, the specified site is the site of the initiating radio. For an All Call initiated by an application, the application explicitly specifies the site.

An All Call whose location is a set of sites (called multi-site All Call) is received by the radios at the specified sites. As in a normal talkgroup, the system administrator can configure the sites that are statically associated with the multi-site All Call group using Radio Management (RM). The DMR specification supports only one multi-site All Call group.

An All Call whose location is all the sites in a system (called system-wide All Call) is received by the radios at any sites. A Capacity Max system does not support a system-wide All Call. If a system contains fewer than 16 sites, the multi-site All Call can be associated with all the sites, and in that case the multi-site All Call acts as the system-wide All Call.

Control of All Call Capability for a Radio

Using Subscriber Access Control (SAC), a system administrator can enable or disable capabilities for a radio (including the voice application) to initiate a site-wide or multi-site All Calls.

There is no control on reception of an All Calls. All radios are expected to receive All Calls.

Late Join Capability

An All Call is announced over all busy trunked channels of the sites that are associated with the All Call. The announcement causes the radios listening to non-emergency calls to move to the channel where the All Call is in progress.

The following radios may either fail to join an All Call or join the All Call only after their call ends:

- Transmitting radios: While transmitting, a radio cannot listen to an announcement.

- Radios on the data revert channel: Announcements are not made over data revert channels.
- Radios participating in an emergency call: An emergency call has higher priority than an All Call.

Limit to Active All Calls at a Site

A Capacity Max system allows only one All Call to be active a time at each site. For example, if a site-wide All Call is active at a site, the system rejects a request to initiate a multi-site All Call associated with that site.

The DMR III standard provides one unique ID to each type of All Call: site-wide, multi-site, and system-wide.

While an All Call is in progress at a site, only emergency calls are allowed to start from the site. Non-emergency call requests from the site are discarded.

Some other features of All Calls are:

- A radio initiates an All Call in the same way as a talkgroup call.
- In Capacity Max, a request for an All Call is never queued. If a channel is not available at a required site, the system preempts an ongoing non-emergency call. If all available channels are busy with emergency calls, the request for an All Call is rejected.

Chapter 7

Capacity Max Telephone Voice Calls

This chapter describes the telephone voice calls in Capacity Max, defines the different phone call types such as radio to phone, phone to radio, and phone to talkgroup calls, and briefly describes the phone architecture and the supported phone interface. The dialing method, access code, overdial, and radio's phone capability control are also explained in this section.

Overview of Phone Architecture and Supported Interface

The telephone voice calls are supported via the MNIS VRC Gateway. A compatible 3rd party phone application is required to be connected to the MNIS VRC Gateway. The landline phone user communicates with the radio users via the phone application and the MNIS VRC Gateway.

Telephone Voice Call Types

The following three phone call types are supported:

Radio to Phone
: Individual phone call initiated from a radio user to a landline phone user.

Phone to Radio
: Individual phone call initiated from a landline phone user to a radio user.

Phone to Talkgroup
: Talkgroup phone call initiated from a landline phone user to a group of radio users. Phone All Call, as a special phone to talkgroup call, is also supported.

The priority of a phone call is the same as a regular voice call type of the same talkgroup or individual involved in the call. That is, for an individual phone call, it is the same as a regular individual voice call; for a talkgroup phone call, it is the same as a regular talkgroup voice call of the talkgroup involved. The phone call can be either clear or encrypted, and there is no concept of emergency phone calls.

Methods of Dialing

The radio supports the following dialing methods:

Manual Dial
: The radio user can manually dial the phone number. This option can be turned on or off via Radio Management. This feature is applicable for display model only.

Address Book Dialing
: A radio user selects the phone number from the radio's phone address book. This feature is applicable for display model only.

One Touch Dialing
: A radio user pushes a programmable button of the radio to dial a pre-programmed phone number.

The dialing method from the landline phone user to a radio or a talkgroup is defined by the 3rd party phone application. Usually, the landline phone user will dial a phone number to the phone application, after connecting, the phone user will be prompted to enter the target Talkgroup ID or radio ID.

Phone Call Answering

When a radio user calls a landline phone user, the phone user can pick up the phone and answer the call like a regular phone call. When a landline phone user calls a radio user or a talkgroup, and if the

target radio user, the talkgroup or a channel is available, the radio or talkgroup will jump to the assigned channel and start the phone call.

Phone Call Handling

The phone call in the radio system is a half-duplex call, unlike a regular duplex phone call, where the user (phone or radio user) cannot talk and listen at the same time. A priority is given to the radio users; when a radio user starts to talk, the system will automatically mute the landline phone user’s voice, and when the radio user is not talking, the landline phone user can start to talk.

Overdial

Overdial is necessary when further information in the form of DTMF digits is required after the phone call is established. Overdial is supported by the display radio models. For example, if a user calls a company with a phone voice prompt system, like a bank, once the call is connected the user may be required to key in numbers or characters which is known as overdial, in order to navigate the system.

Phone Call Ending

The phone call can be ended either by the radio user or the landline phone user. The radio user uses the de-access code to end the call, and can send out the de-access code to the system either manually from the keypad or by pushing a programmable button. The landline phone user can end the call by hanging up or other methods defined by the 3rd party phone application. The de-access code is sent as in-band Dual Tone Multi Frequency (DTMF) tones.

Radio Phone Capability Control

The system administrator can control a radio’s phone capability from the Subscriber Access Control (SAC) in the following ways:

- Radios that can initiate phone calls
- Radios that can receive phone calls
- VRC gateway and thus the phone application, a particular radio uses to initiate phone calls
- Whether a phone ‘All’ call can be initiated from a particular phone application

Radio User Call Type Permissions Control

The system administrator can control a radio user’s capability to initiate certain type of calls such as international, 1–800, 1–900, and others, with the use of an access code. An access code can be pre-configured in a radio or can be left blank, for the radio to prompt the radio user upon phone call initiation. The access code is sent to the phone application, where it is checked if the initiating radio has the permission for the attempted phone call type. There is only one access code for a radio per system, and the access code is sent as in-band Dual Tone Multi Frequency (DTMF) tones.

Chapter 8

Capacity Max MNIS Voice and Radio Command (VRC) Gateway

This chapter briefly describes the MNIS VRC Gateway and the services it supports.

Overview

The MNIS VRC Gateway is a software service, which resides in the Capacity Max System Server (CMSS), and connects to Capacity Max repeaters over an IPv4 network. As it is connected with repeaters over IPv4, wireless control stations are not required by the applications, when they are using a MNIS VRC Gateway.

Wireline voice applications, such as the voice dispatch, voice recorders, and phone gateway, require MNIS VRC Gateway to communicate with a Capacity Max system. Some non-voice wireline applications, which uses radio commands for emergency alarm monitoring, or stun or revive of a radio, also require MNIS VRC Gateway. The applications connect to the MNIS VRC Gateway over the IPv4 network.

Applications can send or receive the following types of calls via the MNIS VRC Gateway:

- Group voice calls, broadcast group calls, site all calls, multi-site all calls, and emergency calls
- OACSU and FOACSU individual voice calls, remote monitor voice calls
- Phone initiated group calls and individual phone calls
- Radio check, call alert, radio stun or revive, and emergency alarm
- Receive Individual voice calls for recording or monitoring. All audio is monitored/recorded by external voice applications such as the voice dispatch, telephony, and audio logging (including Discreet Listening).

The application can also support MOTOTRBO’s end-to-end encryption feature for secure voice communication between the radios and the application. Applications can interrupt a transmitting radio and transmit over the radio. A transmission request during hang time from an application has higher priority than the transmission requests from radios. A system administrator can set the higher priority for the application’s call requests that are waiting for channels.

Gateways Architecture

A MNIS VRC Gateway can have a backup gateway for fault tolerance. Based on the information provided by the MNIS VRC Gateway, an application can switch-over to the backup gateway upon loss of network connection or failure of the primary gateway. Primary and backup gateways can be either co-located or located at different locations for geographical redundancy. A Capacity Max system supports up to 5 pairs of primary and backup MNIS VRC Gateways. Some voice dispatch applications also support redundancy with backup applications, and the redundant application takes over upon loss of network connection or failure of the primary application. The number of MNIS VRC Gateways supported in the system is licensed. If two or more MNIS VRC Gateways are licensed then they can be assigned as primary or backup pairs or as separate gateways.

The number of concurrent voice calls (that is, active talkpaths) supported by MNIS VRC Gateways in a Capacity Max system is also licensed. A MNIS VRC Gateway can be allocated up to 100 talkpaths. The MNIS VRC Gateway keeps a count of the number of talkpaths it is utilizing. The MNIS VRC Gateway rejects a request from a voice application if the request causes the current number to exceed the allocated number. An incoming voice call is not delivered to the voice application if the call causes

the current number to exceed the allocated number. The backup MNIS VRC Gateway does require additional talkpath licenses. The radio commands do not require talkpath license. A MNIS VRC Gateway allows radio commands even when it has zero talkpaths allocated to it. There is no limitation on number of concurrent radio commands.

A MNIS VRC Gateway can support up to 10 independent applications such as the voice dispatch, voice recorders, or phone gateways. A voice dispatch applications have client-server architecture, where the server connects with the MNIS VRC Gateway and multiple operator positions connect to the server as clients. A server accounts as one of the ten applications the MNIS VRC Gateway supports.

Call Flow

An application that needs to participate in a voice call (for example, the voice dispatch) requires a radio ID, and therefore an entry in the Subscriber Access Control (SAC). Using the SAC entry in Radio Management, a system administrator can control the services permitted to the application.

The application registers its ID with the Capacity Max system via the MNIS VRC Gateway. The system uses the registration for routing individual voice call or radio command from a radio to the MNIS VRC Gateway, and the MNIS VRC Gateway uses the registration info to route the individual voice call or radio command to the application.

A site ID is associated with a MNIS VRC Gateway and its backup. To receive a talkgroup call, the site ID of the MNIS VRC Gateway is statically associated with the talkgroup in Radio Management. The system routes a talkgroup call to a MNIS VRC Gateway, only if the site ID of the MNIS VRC Gateway is associated with the talkgroup. An application affiliates a talkgroup to a MNIS VRC Gateway, which uses the affiliation to route the talkgroup calls to the application. The MNIS VRC Gateway allows multiple applications to affiliate for the same talkgroup.

A voice recorder subscribes the following with its MNIS VRC Gateway:

- A list of talkgroups, whose calls it wants to record. The list of talkgroups contains only single talkgroup IDs (for example, TG 9, TG 235, TG 189).
- A list of source radios, whose calls it wants to record. The list of radios contains only range of radio IDs (for example, 1-2000, 6700-6780).

The MNIS VRC Gateway routes the group voice calls and individual voice calls from the radios, whose IDs are in the lists, to the voice recorder.

A phone gateway subscribes a list of source radios, containing a range of radio IDs, whose served phone calls is with its MNIS VRC Gateway.

A MNIS VRC Gateway supports up to 1000 group affiliations, assuming that on the average 3 applications affiliates for a talkgroup. A MNIS VRC Gateway supports up to a total of 5000 radio ID registrations from dispatch applications, and 32 ranges of radio IDs per recorder or phone gateway application.

Chapter 9

Capacity Max MNIS Data Gateway

This chapter briefly describes the MNIS Data Gateway and the services it supports.

Overview

The MNIS Data Gateway is a software service, which resides in a Windows based PC and connects with Capacity Max over an IPv4 network. It connects with repeaters over the IP network, therefore wireless control stations are not required by the application when using the data gateway.

Data Applications

Data applications such as text messaging servers, location servers, telemetry, over the air programming, and over the air battery management, require a data gateway to communicate with a Capacity Max system. The applications communicate with the MNIS Data Gateway over the IPv4 network.

Data applications can send or receive the following types of Layer 2 data packets via the MNIS Data Gateway:

- Unconfirmed data calls to or from a group
- Confirmed and unconfirmed data calls to or from an individual radio
- Receive high efficiency location data from a radio

Encryption can be enabled for secure data communication between the radio(s) and the MNIS Data Gateway.

A MNIS Data Gateway supports transmission of data to radios over the trunked channels and reception of data from the radios over the trunked channels, data revert channels and enhanced GPS revert channels. The MNIS Data Gateway can directly transmit data to or receive data from repeaters at a site of the Capacity Max system. This eliminates the need for deploying wireless control station within the RF coverage of a site. In Capacity Max system, rather than requiring channels at other sites, a data revert channel always works in single site mode. Therefore individual data calls to data applications only use channels at the radio's source site. This improves the overall data capacity of the system when utilizing the data gateway. As the MNIS Data Gateway can transmit or receive data from any site; radios can roam to any site and are still able to communicate with the data application.

Multiple data applications can be supported by one MNIS Data Gateway. It is recommended the data application is located on the same PC with the data gateway. However, if this is not possible then:

- Either, the application can be installed on a different PC as long as the network routing is configured for routing the data messages between the application and the MNIS Data Gateway.

  NOTICE: Some applications can send group data, only when they are installed on a PC having a MNIS Data Gateway.

- Or, the application should have client-server architecture. In that case, the server is co-located with the data gateway and multiple clients can connect to the server application.

The number of MNIS Data Gateways supported in the system is licensed, and a Capacity Max system supports up to 5 MNIS Data Gateways.

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Chapter 10

Capacity Max Data Revert Channel

This chapter describes the capabilities of the Enhanced GPS Revert channel supported in Capacity Max.

Overview of Enhanced GPS (EGPS) Revert Channels

A Capacity Max site supports up to 12 Enhanced GPS Revert channels (that is, 6 EGPS Revert repeaters) for radio to server data. These channels increase the supported call load without impacting call loading on the trunked channels. The Enhanced GPS Revert channel supports two types of data payload format, which are IP Data and High Efficiency Data. Unlike other wide area solutions, in Capacity Max an Enhanced GPS Revert Channel is not shared across all sites (wide area), rather it is local to the site.

Enhanced GPS Revert Channel for IP Data

IP Data can be sent on the Enhanced GPS Revert channel via unconfirmed clear and unconfirmed encrypted radio to server location data. The location data can be indoor location or outdoor location. This type of channel schedules the location updates of a radio into a time window.

Data reliability is primarily a function of repeater loading, when a radio misses its scheduled update when involved in a call, and RF conditions. The duration of the time window (that is, the window size) is a function of the amount of data requested by the location server. Third-party developers can provide which window size they require for their location server. This type of channel supports update rates of 30 seconds, 1 minute, 2 minutes, 4 minutes, and 8 minutes where the channel loading can be set to limit at 90%, 75%, 60% or 45%.

The following table shows the number of updates per minute per channel for Window Size and Channel Loading Limit. Refer to Number of Data Revert Repeaters Selection on page 117 for guidance on the Channel Loading Limit. The update rate does not need to be the same for all radios operating on the enhanced GPS revert channel. The typical window size is 7, and the typical channel loading is 75%.

Table 2: Number of Updates per Minute per Channel (Slot)

	Number of Updates per Minute per Channel (Slot)			
Window Size	**90%**	**75%**	**60%**	**45%**
5	180	150	120	90
6	150	125	100	75
7	128	107	86	64
8	112	93	75	56
9	100	83	66	50
10	90	75	60	45

Enhanced GPS Revert Channel for High Efficiency

High Efficiency Data can be sent on the Enhanced GPS Revert Channel via unconfirmed clear radio to server outdoor location data as well as radio to server raw data from an XCMP connected device. Typically the XCMP connected device is the Option Board. This type of channel schedules the High Efficiency Data of a radio into a time window.

Data reliability is primarily a function of repeater loading, when a radio misses its scheduled update while involved in a call, and RF conditions, though other parameters can impact. A window size of one is used when the server is connected through the MNIS Data Gateway, and a window size of two is used when the server is connected through a wireless control station. This type of channel supports update rates of 7.5 seconds, 15 seconds, 30 seconds, 1 minute, and 2 minutes.

The following table shows the number of updates per minute per channel for Window Size and Channel Loading Limit. The update rate does not need to be the same for all radios operating on the enhanced GPS revert channel.

Table 3: Number of Updates per Minute per Channel (Slot)

	Number of Updates per Minute per Channel (Slot)			
Window Size	**90%**	**75%**	**60%**	**45%**
1	904	752	600	456
2	448	376	304	224

For data through an Over-The-Air (OTA) Data Gateway, high efficiency data signaling carries longitude and latitude information to the application.

For data through an MNIS Data Gateway, high efficiency data signaling supports options that carry the following limited information to the application:

- longitude, latitude, horizontal speed (138 mph maximum), direction and time
- longitude, latitude, pin status and time.

If the customer requires more information than high efficiency data can support, then IP data must be used.

Enhanced GPS Revert Channel Data Payload Format Comparison Chart

Table 4: Enhanced GPS Revert Channel Data Payload Format Comparison Chart

Revert Channel Type	Data Reliability	Data Types Supported	Location Parameters	Supported Radios per Time Slot
IP Data	Unconfirmed	Outdoor Location and Indoor Location	Full	107 (1)
High Efficiency Data	Unconfirmed	Outdoor Location and OB Data	Limited	752 (2)

(1) 1 minute update rate with window size of 7 and 75% loading

(2) 1 minute update rate with 75% channel loading through MNIS Data Gateway

Chapter 11

Capacity Max Location Services

This chapter describes how to determine the Capacity Max radio's location. A Capacity Max radio's location may be tracked indoors, outdoors or both with appropriate radio hardware, 3rd party hardware support for indoor location only, and 3rd party application support. The third-party applications connect into the radio network via an IP Data Gateway or OTA Data Gateway. Radios can send their location data to the third party application on a trunked channel, a data revert channel or, an Enhanced data GPS (EGPS) revert channel.

Overview

The MOTOTRBO location feature allows a dispatcher to determine the current location of a radio on a display map. The dispatcher can obtain the radio's location (latitude or longitude), or the location combined with other information about the environment such as horizontal speed, direction, and others, that allows value-added services, like tracking of resources.

Location Services via Global Navigation Satellite System

MOTOTRBO systems enable location services via two complementary functions. Firstly, the MOTOTRBO mobile and portable radio portfolio, which includes models that are equipped with a built-in Global Navigation Satellite System (GNSS) receiver. The acquisition of location data is done by a GNSS receiver inside the radio, and is dependent on the GNSS receiver receiving accurate signals from the earth-orbiting GNSS satellites. However, the GNSS receiver may not work well indoors or in environments, where the sky is largely obscured.

Secondly, the integrated data services capability of the MOTOTRBO system, allows well equipped mobiles and portables to transmit their location coordinates over the radio system, to a receiving application that displays radios geographic locations on a high resolution map. This third party supported receiving application is the second part of the system and connects to the radio network through an IP Data Gateway or OTA Data Gateway.

Global Navigation Satellite System (GNSS)

Based on the radio hardware, the following systems are supported for the outdoor location solution.

- GPS
- GLONASS
- Beidou
- Galileo
- QZSS

Some radio's hardware supports multiples systems at once, and allows the selection of multiple systems. This will reduce Time To First Fix (TTFF) in areas where multiple GNSS solutions exist, as an increased number of satellites are now available.

GNSS Performance Specifications for GPS

Table 5: GNSS Performance Specifications for GPS

GPS Receiver	Portable	Mobile

Table continued…

TTFF (Time To First Fix) Cold Start	< 2 minutes	< 1 minute
TTFF (Time To First Fix) Hot Start	< 10 seconds	
Horizontal Accuracy	< 10 meters	

NOTICE: Accuracy specifications are for long term tracking (95th percentile values > 5 satellites visible at a nominal -130 dBm signal strength).

The GNSS erformance specifications for GPS are described as follows:

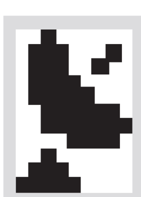
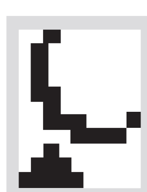
Cold Start
A cold start scenario occurs when the radio is first powered up, and the GPS receiver is attempting to acquire its first position lock. In this scenario, the GPS receiver only has a valid almanac stored; it does not have any valid satellite ephemeris data nor valid real-time clock synchronization. Almanac data is stored in a non-volatile (persistent) memory, and is valid for approximately one year. The GPS receiver regularly updates the almanac data; therefore it will always be valid unless the radio is powered off for more than one year. The almanac data provides a mapping of the GPS satellites position in the sky in relation to a real-time clock.

Hot Start
A hot start scenario occurs when the GPS receiver attempts to acquire a new location fix after a previous fix had occurred recently. In this scenario, the GPS receiver has valid satellite ephemeris data, a valid almanac, and valid real-time clock synchronization.

TTFF
Time to First Fix indicates the time the GPS receiver takes to determine its first or subsequent position lock. This is determined largely by the time taken to download a full satellite ephemeris or satellite orientation packet with a data rate of 50 bits per second (bps), and how long it takes for the GPS receiver to reach the relevant satellite in its Scan List. In a cold start, the Scan List includes all of the 24 orbiting satellites. The GPS receiver samples each satellite for a certain amount of time to determine if it is visible or not before moving to the next satellite. The receiver continues to do this until it detects a certain number of visible satellites and can determine an approximate location, thus helping the receiver to truncate the Scan List. In a hot start, the receiver already has most, if not all, the data needed to calculate its position. Therefore, no scanning is needed and minimal downloading is necessary to calculate position, resulting in a lower time to acquire a positional fix.

GNSS Services for Radio Users

When the GNSS location service is enabled, an icon is displayed on the radio. The absence of this icon indicates that the location service is either disabled or radio does not contain a GNSS receiver. The icon shows a full satellite dish when good GNSS signals are detected, and an empty satellite dish when the radio is receiving poor GNSS signals.

Good Signal	Poor Signal	Disabled
		*no icon*

Selected radio models allow users to view the current location information, through the front panel menu by selecting Utilities -> Radio Info -> GPS Info. Displayed information includes longitude, latitude, altitude, velocity and number of satellites of all selected GNSS systems.

With the exception of pressing the Emergency button, a radio user cannot trigger a location update to a location application server. In general, the radio user does not have to take any action in this process, as the radio transmits the location coordinates automatically over the system.

Location Services via Bluetooth Low Energy (BLE) and iBeacons (Indoor Location)

The MOTOTRBO Indoor Location feature requires the radio to support BLE support, the installment of iBeacons throughout the indoor area of interest, and the marking in the application of the iBeacon locations. The radio periodically scans for iBeacon broadcasts, and sends this information to the application where the radio's location is triangulated. The radio does not support beacon technologies other than iBeacon.

Services Provided to a Location Application

For all the services, a location application server is required to send an explicit request to the radio. A radio does not provide unsolicited location update to a location application server. When the radio turns on the radio registers with the system. The location application learns that this radio is on the air, and will make an explicit request for location updates if it is configured to track the location of the radio. The explicit request may be omitted if persistent LRRP is enabled in the radio. This reduces the amount of server to radio messaging at power on.

Well equipped radios transmit an update of their location coordinates over the radio system in response to 5 different service methods, as follows:

Single Location Update

The location application server wants to know the current location of a radio user. In this case, the application sends a request for a single location update. Single location update is used to track the location of a radio user by a location application server, but is an inefficient use of air interface.

Periodic Location Updates

Location tracking allows a location application server to periodically get the location of a radio user by sending a single location request that contains the time interval between updates. The radio continues to update its location periodically at the specified time interval until the request is cancelled by the location application server.

On Emergency

A radio will send its location after the user triggers an emergency alarm or an emergency alarm and call request. The location update is sent only to the location application server which had previously sent an active location request for location updates from that radio upon an emergency event. This location update is sent by the radio only after the processing of emergency is completed. For example, for Emergency Alarm with Call, the location data is only sent after the emergency alarm is acknowledged and the initial Emergency Call is completed. This happens because the location data is sent as a data burst which has lower priority than the voice call.

Event Driven Update

Location tracking allows a location application server to get the location of a radio user by sending a single location request that contains the event used to trigger an update. The radio updates its location upon this event until the request is cancelled by the location application server. The supported event is GPIO pin change.

Distance Driven Update

Location tracking allows a location application server to get the location of a radio user by sending a single location request that contains the distance traveled between updates. The radio updates its

location after traveling the specified distance from the previous update until the request is cancelled by the location application server.

See third party offerings for specifics on the services they provide.

Location Application Connection to the Radio Network

The location application connects into the radio network through either an IP data gateway or an OTA data gateway.

Location Data Channel Types

Both indoor and outdoor location data can be sent on a trunked channel or an Enhanced GPS (EGPS) Revert channel with a data payload format of IP Data. Outdoor location can also be sent on an Enhanced GPS Revert channel with a data payload format of High Efficiency Data. When sending on a trunked channel, the radio requests and is granted the channel using control channel signaling. This method applies a load on the control channel and reduces the number of calls that can be supported at a site. Sending location updates on a trunked channel is not recommended for sites supporting a high volume of traffic. For high traffic volume sites it is recommended to use Enhanced GPS Revert channels. EGPS Revert channels do not put any load on the control channel. Specifics on the EGPS Revert channel can be found in the chapter Capacity Max Data Revert Channel on page 35.

Chapter 12

Capacity Max Remote Monitoring

This section describes the Remote Monitoring feature which is also known as Ambient Listening.

Overview of Remote Monitor

Remote Monitor is a feature that allows the call initiator to activate a target radio's microphone and transmitter. The monitored target radio's PTT is activated without giving any indication to the monitored radio user, when the call is setup. If a radio is already in a call, the Remote Monitor request is not queued.

A Remote Monitor call is a one way individual voice call, in which the monitored or the called radio un-mutes its microphone and transmits the ambient sound for a configured duration on the trunked channel.

Applications connected to an MNIS VRC Gateway (for example, the Console) and radios can initiate a Remote Monitor. A radio user can select a contact like an individual radio, from the menu and can initiate Remote Monitor to that contact.

Radio Configuration

The remote monitor feature can be customized by configuring the radio using Radio Management. The following are the configurations that can be done:

- The duration of the remote monitor call is configurable in the radio.
- The remote monitor feature can be enabled or disabled in the radio. When the feature is disabled, the radio cannot be remotely monitored.
- The remote monitor feature can be enabled selectively, when the radio is in emergency mode; therefore the target radio can only be remotely monitored, when it is in emergency mode.

System Server Configuration

The remote monitor feature has two controls for each radio ID in the System Access Control (SAC), of the Capacity Max System Server (CMSS). One control is for initiating a remote monitor, and the second control is for receiving a remote monitor. The system checks the following conditions during a remote monitor call setup:

- The initiating radio ID is registered to the system
- Remote monitor capability is enabled in SAC for initiating radio ID
- The monitored radio ID is registered to the system
- Receive remote monitor capability is enabled in SAC for monitored radio ID

Remote Monitor Duration Recommendation

The monitored radio transmits for the configured remote monitor call duration; thus it is recommended to keep the configured duration to a small value like 10 or 20 seconds, for efficient trunk channel usage. Occasionally if it is required to monitor a radio for longer duration, remote monitor call to the same radio can be initiated multiple times.

NOTICE: The target radio ends the remote monitor call, when the target radio user initiates a call during remote monitor transmission.

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Chapter 13

Capacity Max Radio Check

This chapter describes the Radio Check feature.

Overview of Radio Check Feature

The Radio Check feature allows an application to determine if a radio is available in the system without disturbing the radio user. If a radio is registered to the system, and is in contact on the control channel at any site, the radio responds with an acknowledgement to the radio check. The Capacity Max system performs the radio check once, and updates the initiator on the status of the radio check. The initiator has to do the retries, if a radio check fails.

A Radio Check fails in any of the following conditions:

- The target radio is not registered to the system
- The target radio is in a call on a trunked channel
- The target radio is sending data on a data revert channel
- The target radio is out of RF coverage area or switched off
- The feature is not enabled in the Subscriber Access Control record of the initiating application.

Applications connected to a MNIS VRC gateway can initiate a radio check, while radios like the subscriber units cannot initiate a radio check.

Configuration in the Capacity Max System Server (CMSS)

The Radio Check feature has to be enabled for the initiating application's (for example, the console) radio ID in the System Access Control (SAC) of the CMSS. The source radio ID and target radio ID have to be enabled in the SAC. SAC configuration is not required for radio check receive functionality. All radios receive the radio check by default.

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Chapter 14

Capacity Max Call Alert

This chapter describes the Call Alert feature.

Overview

The Call Alert feature allows a radio user or a dispatcher ‘A’ to send an alert to another radio user ‘B’, where the radio user ‘A’ is requesting the radio user ‘B’ to call back the radio user ‘A’, when the radio user ‘B’ becomes available. Voice communication is not involved in this feature. Call Alert is a Motorola proprietary feature, and it is available in both Advantage Mode and Open System Mode. In Open System Mode, both radios must be MOTOTRBO radios.

Call Alert Feature Description

To use the Call Alert feature, the calling radio user specifies the ID of the target radio. This can be done in several different ways, such as the ID can be entered manually via the keypad, by selecting an ID from a Unified Call List (UCL), or by using the Last Number Redial (if any).

On receipt of a Call Alert, the target radio plays an alert tone to the user and displays the calling radio’s ID. The duration of the alert can be configured using Radio Management. The target radio user can call back the Call Alert source by pressing PTT, by pressing PTT to talkgroup and having Call Alert go straight to call log, or can clear the alert tone by pressing back or home key. While the target radio is alerting its user, the target radio continues to send GPS transmissions (if any).

A Call Alert fails in any of the following conditions:

- Source or the target radio is not registered to the system
- Source radio does not have call alert enabled in the SAC
- Target radio is in other call on a trunked channel
- Target radio is sending data on a data revert channel
- Target radio is out of RF coverage area or is switched off

Call Alert Initiation

Applications connected to a MNIS VRC Gateway can initiate a Call Alert. Radios can also initiate Call Alerts.

Call Alert Feature in Subscriber Access Control (SAC)

The Call Alert feature has to be enabled in SAC for the initiating radio or application (for example, console) radio ID using RM. The system checks that the source and target radios are registered to the system, and the call alert feature is enabled in SAC for the source radio before processing the call alert request. There is no SAC configuration for receiving a call alert. All the radios receive a call alert by default.

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Chapter 15

Capacity Max Emergency Handling (Alarm and Call)

This chapter describes the ergonomics of the initiating radio, the process of selecting an emergency talkgroup, the ergonomics of receiving an emergency, the process of sending location on emergency, and the feature interaction while in emergency. In addition, this section discusses how Capacity Max prioritizes emergencies and describes the available emergency modes: Alarm Only, Alarm and Call, and Alarm with Voice to Follow.

Overview

Capacity Max enables a radio user in distress to send an emergency alarm, and optionally emergency voice, to a talkgroup monitored by a voice console operator. Upon reception of an emergency alarm, the console provides an audible and visual indication of the emergency, and the initiating radio ID is displayed. Depending on configuration, emergency voice may follow between the initiating radio and the console operator. When the condition that led to the emergency alarm is resolved, the console operator clears the alarm locally. When the initiating radio user clears the emergency on the initiating radio, the emergency is terminated.

NOTICE: Radios can receive emergency alarms/calls. The talkgroup will be monitored by another radio or voice application.

Emergency Initiation

Each mobile radio can program the emergency button to any of the programmable buttons, whereas a portable radio can only use the orange button as the emergency button. An emergency can also be triggered externally through a footswitch, a mobile application, or any other applicable accessory. Pressing the emergency button causes the radio to enter emergency mode and begin its emergency process.

Alarm Type

The alarm type determines the ergonomics of the initiating radio upon entry to emergency mode.

Regular

When a user initiates a regular emergency, the radio provides an audible and visual indication to show that it has entered emergency mode. The audible indication is to notify the radio user of successful entry to emergency mode.

Silent

When a user initiates a silent emergency, the radio suppresses all indications of the emergency status on the initiating user's radio. In addition, all received voice is muted. The voice is muted so that responses from the voice console do not inadvertently indicate the emergency state. This feature is valuable in situations where an indication of an emergency state is not desirable.

When the user breaks radio silence by pressing the push-to-talk (PTT) button and speaking, the silent emergency ends, audible and visual indications return, and the radio returns to its normal unmute rules.

Silent emergency has no effect on data. It is the responsibility of the end user to make sure data is not sent to a terminal that would divulge any emergency state. Transmission of data does not clear a silent emergency.

Silent with Voice

When a user initiates a silent emergency with voice, the radio suppresses all indications of the emergency status on the initiating user's radio, but received voice is not muted. This feature is valuable in situations where an indication of an emergency state is not desirable.

When the user breaks radio silence by pressing the PTT button and speaking, the silent emergency ends, and audible and visual indications return.

Silent emergency has no effect on data. It is the responsibility of the end user to make sure data is not sent to a terminal that would divulge any emergency state. Transmission of data does not clear a silent emergency.

Emergency Search Tone

When a user initiates an emergency, the radio provides a loud and attention grabbing tone. The tone is to help people locate and identify the emergency initiator.

The emergency search tone starts when the emergency starts, and ends when the radio exits the emergency. The tone is temporarily suspended when the radio is transmitting or receiving.

The tone is provided whether the "All Tone Disabled" option is activated or not. This tone is mutually exclusive with the silent emergency setting.

The option can be configured to specify where to route this emergency search tone or incoming voice; to the radio's internal speaker or the accessory. When an accessory is not attached, the tone is routed to the radio's internal speaker automatically.

Emergency Talkgroup

Emergency alarms and emergency voice are addressed to a talkgroup. The selection of which talkgroup makes a major difference in the overall operation of the emergency. The emergency talkgroup is configured as the contact name in the emergency system set within Radio Management.

Tactical

Sending an emergency on the currently "selected" talkgroup (sometimes referred to as a "tactical" emergency) allows everyone in the currently selected talkgroup to monitor the emergency situation. Each talkgroup may have a dedicated dispatcher that handles emergency situations, or the entire group may need to be notified that someone in the talkgroup is in emergency.

In a system with many talkgroups, a tactical configuration requires the dispatcher to monitor every talkgroup for emergencies, which could become cumbersome. In addition, the remaining members of the talkgroup must yield use of the talkgroup to the individual in emergency.

Reverting

Sending an emergency on a predetermined talkgroup (referred to as "reverting") allows users to leave their currently selected talkgroup and communicate to the dispatcher on a dedicated emergency talkgroup.

This reverting function allows a dispatcher to monitor the dedicated emergency talkgroup and have all other users revert to the dispatcher in case of an emergency. This function minimizes the possibility of supervisors missing emergencies on one talkgroup while monitoring other talkgroups. It also allows a clear channel of communication for the user initiating the emergency and the dispatcher. Other radio

users may not be aware of the emergency situation unless they monitor the dedicated emergency talkgroup.

After the radio user clears the emergency, the radios revert to the talkgroup they selected before the emergency occurred.

The use of a dedicated emergency talkgroup requires the talkgroup to be statically assigned to sites and gateways. Emergency revert talkgroups are not affiliated on power up, channel change, or on roam.

Reception of an Emergency Alarm or Call

Emergencies are best received and handled at voice consoles. The larger display allows the dispatcher to effectively handle numerous simultaneous emergencies. The methods vary depending on console vendor.

Emergency Alarm Indication

The radio retains a list of received emergency alarms so that the radio user can monitor multiple emergencies. Once cleared, the emergency alarm is removed from the list, and the next one is displayed. These emergencies are displayed in a last-in-first-out sequence.

The monitoring radios can hide the emergency alarm list, so the user can contact service personnel to attend to the received emergency situation. The channel where the emergency alarm was received is displayed to aid the supervisor when changing channels. Delivery of emergency alarms is only confirmed inbound over the air to the system. They are not confirmed outbound to the radios.

The emergency alarm indication is provided only to radios with this option enabled and only while they are monitoring the control channel when the emergency alarm is initiated.

Emergency Call Indication

If a user follows the emergency alarm with a voice call while in emergency mode, that user's transmission contains an embedded emergency indication. Radios can be configured to display this embedded emergency indication when they receive an emergency call.

The indication is not persistent. The indication is only present while the radio is receiving an emergency call.

Transmission of Location Information During an Emergency

A location equipped radio can send its location to a location data application when an emergency is triggered. The location data application requests the radio to send location on the emergency event when it requests periodic location updates.

Feature Interaction During an Emergency

When a radio is in emergency mode, features that may distract that user from communication with the supervisor are blocked. For example, the user cannot initiate an individual call or talkgroup call from the address book, or other command and control functions. In addition, any other receive talkgroups that were previously configured for that user are not monitored.

When the radio exits emergency mode (for example, after the user turns the radio off and on, after a long or short press of the emergency button, depending on the radio configuration), the features blocked during the emergency return.

Prioritization of Emergencies

This section describes the methods used to prioritize emergencies within the system.

Call Preemption at Busy Sites

If no trunked channels are available, the system interrupts (preempts) ongoing calls and grants the emergency call. If a radio is transmitting on the preempted channel at the same site as the emergency initiator, the system directs that radio to immediately stop transmitting, which prevents interference with transmissions by the emergency initiator.

Radio transmissions that were occurring on the preempted channels at other sites are not interrupted, but their transmissions are not repeated. When any interrupted radio dekeys, it returns to the control channel. Other calls are not interrupted.

Emergency Calls Announced on Trunked Channels

The system announces ongoing emergency calls in the embedded signaling of other ongoing calls. This function allows radios to join the emergency call even while participating in other calls. In order to use this feature, radios must have the emergency talkgroup as their primary talkgroup or in their talkgroup receive list.

Longer Emergency Call Hangtime

The system allows for emergency calls to have a longer call hangtime than other talkgroup calls. A longer call hangtime holds the assigned trunked channel longer. This function aids in call continuity and decreases access time for in-call retransmissions. The emergency call hangtime is configurable within Radio Management.

Increased Number of Channel Access Attempts

The system allows for emergency alarms and calls to have more channel access attempts than other call types. Allowing more channel access attempts increases the opportunity for emergency calls and alarms to access a channel during poor coverage or heavy call volumes.

Emergency Mode

This section describes the configurable methods to process an emergency.

Emergency Alarm Only

When configured for Emergency Alarm Only, the emergency process consists only of the emergency alarm delivery. The emergency ends when an acknowledgement is received from the system, or when channel access attempts have been exhausted. In most conditions, an acknowledgement is returned from the system quickly. No voice call is associated with the emergency when operating as Emergency Alarm Only.

Emergency Alarm and Call

When configured for Emergency Alarm and Call, the emergency consists of sending an alarm followed by the ability to perform an emergency call. The emergency alarm delivery is complete when an acknowledgement is received from the system, or when channel access attempts have been exhausted.

When emergency alarm delivery is complete, the radio remains in an emergency state. Any follow-up PTT initiates an emergency call.

An emergency call includes an embedded emergency indication. If the user presses the PTT button before the radio sends an emergency alarm, the radio stops sending the alarm and starts the emergency call. While in the emergency mode, all subsequent voice transmissions are emergency calls.

The user remains in emergency mode until the user manually clears the emergency. The only way to reinitiate the emergency alarm process is to reinitiate the emergency.

Emergency Alarm with Voice to Follow

When configured for Emergency Alarm with Voice to Follow, the emergency consists of sending a single emergency alarm followed by an automatic transmission of an emergency call. This automatic transmission is referred to as “hot microphone”.

The radio only sends one emergency alarm regardless of the presence or absence of channel activity, and then without waiting for an acknowledgement, the radio immediately activates the microphone and initiates an emergency call without the need of the user pressing the PTT button.

The duration of the hot microphone is configurable (TX Cycle Time). The transmission is considered an emergency call and therefore includes the embedded emergency indication. Once this hot microphone duration expires, the radio stops transmitting but remains in emergency mode. Any follow-up PTT initiates an emergency call and includes the embedded emergency indication. The radio remains in the emergency mode until the user manually clears the emergency.

Interaction Between Voice to Follow and Location on Emergency

When configured for Emergency Alarm with Voice to Follow, the radio continues to transmit voice for the duration of the provisioned hot microphone timer (TX Cycle Time). Because voice has priority over data, any data is queued while voice is transmitting, including the location update that triggered the emergency. The location data cannot be delivered until after the radio stops transmitting voice and after the repeater hangtime has expired. The location data has no additional priority over other data queued in the radios, or over any traffic on the channel. Therefore, if the radio in emergency has pending data queued or if the channel is busy processing other traffic, its delivery may be delayed.

When Emergency Alarm with Voice to Follow and location on emergency are in use, the hot microphone timer should be set at maximum 30 seconds. Because data messages do not stay in the queue forever, 30 seconds is short enough to give the location data a chance to be transmitted without timing out. Also, if the hot microphone timer is set to an interval longer than 30 seconds, and the location update rate is close to the same value, other location messages may start to fill up in the queue while the voice transmission is processing.

When a user is transmitting during the hot microphone timer interval, there is no way to communicate back to that user. Most users can explain their situation in less than 30 seconds and require some feedback from the emergency dispatcher much sooner. Therefore, a short timer interval is recommended, and if additional monitoring is required, the remote monitor feature can be utilized. Long timer intervals should be used only in specialized applications.

Hot Microphone Cycles

The radio can be configured for one to ten hot microphone cycles. A cycle consists of a period of transmitting with a hot microphone (TX Cycle Time) and a period of receiving (RX Cycle Time). One cycle consists of the TX cycle time and the RX cycle time. This cycle time provides the dispatcher a designated duration to respond to the initiator.

Use of short TX and RX cycle times (for example, one second) may result in voice being truncated as the radio quickly and automatically cycles between transmit and receive. Use of longer TX and RX cycle times (greater than ten seconds) may result in long wait times before the radio automatically cycles, which means a long wait for responses. Implementing a hot microphone cycle may require great discipline and practice between the radio users and the dispatcher. This feature should only be used in specialized applications.

Any PTT during the hot microphone cycles initiates an emergency call. The next cycle resumes after the release of the PTT. After the cycles have ended, the radio remains in emergency mode. The user can manually clear the emergency to stop the cycles and exit emergency mode.

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Chapter 16

Capacity Max Multi-Site Roaming

This chapter describes the roaming feature, its aim, and sub-features in the Capacity Max multi-site environment.

Overview

The roaming feature aims to reduce the disruption in the communication between the radio and the infrastructure, when a user is moving from site to site. Both the radio and the infrastructure play a role in roaming. In the radio, the roaming feature runs in the background with minimal interactions with the user. The radio monitors the current active control channel of the current site that the radio registers with and as necessary all the active control channels of the neighboring sites. The radio decides due to various reasons, when to leave the current site and start searching for a better site.

The infrastructure plays a role in announcing the information about the neighboring sites, so that the radio can search the sites from its neighborhood, before searching for the rest of the sites.

The radio may be engaged in a call while roaming and need to hand over the call. Capacity Max supports a proprietary call handover for a voice talk group call that reduces any audio holes. This call hand over is supported only when the radio is in a voice receiving or in a call hang time state.

The Capacity Max system supports roaming only among the sites that are configured into the radio or learned through over the air announcement. Roaming between sites of a different network or system types, or to an unknown / unconfigured site is not supported.

Multi-Site Network

From roaming perspective Capacity Max infrastructure is composed of networks, location areas, sites, and control channels. A multi-site network has more than one site. A site can have one or more candidate control channels, with one candidate control channel always being the active control channel.

As defined in the DMR standard, several sites in a network can be grouped into a location area. In the Capacity Max infrastructure, a location area consists of only one site for efficient channel usage. The radio does not support location area configuration when it is used in a Capacity Max Advantage Mode or Open System Mode. The radio provides location area configuration only when it is used in a Capacity Max Open Radio Mode.

Site Neighborhood

At any point of time, the radio registers only with one site, and operates within its coverage. This site is referred to as the home site and is defined as the site that the radio currently registers with. The rest of the sites in the network are referred to as sites that are adjacent sites or non-adjacent to the home site. Due to roaming, a radio may have a new site as its new home site, and thus new set of adjacent and non-adjacent sites.

Site adjacency information is configured in the infrastructure. The radio learns this adjacency through the Over-The-Air announcement, which is sent via the active control channel of the home site. Therefore, the radio is able to recognize the sites that are adjacent and that are non-adjacent to the current home site, every time the radio roams from site to site.

The home site, as well as the adjacent and non-adjacent sites reflect a dynamic site neighborhood which changes following the radio roaming activity.

Received Signal Sampling

The radio periodically samples and measures the received signal strength of the active control channel of the home site. When it is measured lower than the *RSSI Sampling Threshold*, a roaming procedure is attempted by sampling all the active control channels of the adjacent sites, after each sampling of the home site. When the signal strength of the home's active control channel is higher or same as the *RSSI Sampling Threshold*, the radio does not sample the active control channels of the neighboring sites. This is because roaming is not needed. Sampling of the control channel is done without impact to audio or control channel operation.

The radio validates and filters the raw sampled signal to prevent adverse effects of the signal fluctuation on the roaming. The radio updates the last valid and filtered signal of home and each adjacent site.

Roaming

Upon completion of one round of periodic signal sampling, the radio evaluates the favorableness of the home and adjacent sites. If the home is sufficiently favorable, the radio stays at the home site. If there is an adjacent site that is more favorable than the home site, the radio leaves the home site and starts searching for a better site.

Various conditions and configuration parameters are considered in calculating the favorableness of a site. Among those parameters are site preference level, site trunking condition, failures experienced by the radio on the site, and the sampled received signal. In a regular scenario without involving any failures, the sampled received signal is the main factor in determining the favorableness. The decreasing or increasing strength of the sampled received signal indicates whether the radio is moving away from the site or moving closer to the site. Moving away from the site causes the site becomes less favorable to roam to, whereas moving closer causes the site becomes more favorable to roam to.

During searching, when the radio finds, synchronizes and validates successfully a candidate control channel of a site, the radio starts registering with the site. Upon successful registration, the radio completes the control channel acquisition process and starts monitoring the control channel at the new site. Roaming can fail while validating or while registering, which causes the radio to continue site the searching.

Roaming can also be triggered by failure conditions (for example, loss of control channel, site trunking, repeater and network equipment) at the home site, or a manual site search request initiated by the user. Roaming triggered by a manual site search request is called manual roaming. Manual roaming is prevented when the radio is setting up a call.

Site Hunting

Hunting or searching site to attempt is done by stepping through all candidate control channels of a site, and possibly all sites of the network by following the defined hunting sequences, which are short hunting, long hunting, and comprehensive hunting. In each step the radio attempts to synchronize with and validate the control channel, and if successful, register with the site.

Upon starting the hunting, radio performs short hunting, by stepping through the candidate control channels of the home and adjacent sites, which are orderly listed based on their favorableness. Upon exhausting this all site list, and if no candidatecontrol channel can be qualified successfully, the radio repeats the short hunting four times, before it starts a long hunting sequence. During the long hunting, the radio steps through the candidate control channels of the non-adjacent sites. The non-adjacent sites are orderly listed as they appear in the site configuration. Upon exhausting this site list, and if no control channel can be qualified successfully, the radio starts a comprehensive hunting sequence.

During the comprehensive hunting, the radio steps through the known frequencies based on the fixed channel plan. The radio steps through the channel IDs that are convertible to an absolute frequency through the fixed channel plan mapping. Comprehensive hunting is configurable, (i.e. can be enabled or /disabled) only when the radio is configured for a Capacity Max Open System or Capacity Max

Advantage mode, otherwise comprehensive hunting is always disabled. The execution of the comprehensive hunting is limited to 10 seconds. When it expires, because of no frequency can be successfully qualified as a control channel, the radio suspends the comprehensive hunting and restarts the hunting process from the short hunting.

The radio stays in an endless loop of the hunting sequences (short, long and comprehensive), as long as no candidate control channel can be validated successfully. The radio enters an out-of-range state, after attempting all the configured candidate control channels but none can be validated successfully. An audiovisual indication is given to the user about the out-of-range state.

A commanded hunting is performed when the radio is commanded to go to a particular control channel's frequency. This feature is supported by the radio when working on an infrastructure that supports DMR standard for commanded hunting. The Capacity Max infrastructure does not support commanded hunting.

Control Channel Qualification

While hunting the candidate control channels, the radio attempts to qualify it. Qualification can be successful which leads the radio to acquire and register with the site. If qualification fails, the radio proceeds with the next candidate control channel of the same site or with the next site by following the hunting sequence.

During qualification, the following information is validated within a limited time: signal strength, frame synchronization, color code, slot and, DMR system parameters. If the time expires, and any validation fails, the radio fails the candidate control channel.

Failure Handling

After successful registration, the radio starts monitoring the control channel to detect possible failures such as loss of frame synchronization, detected invalid color code, or unmatched detected DMR system parameters. These failures can cause communication with the home site, cannot be maintained, and will trigger the radio to start searching a new home site.

When the communication between the home site control channel repeater and the trunking controller fails, the home site enters a site trunking condition. A call cannot be repeated into or out of the home site. A site trunking condition triggers the radio to attempt roaming.

When the radio is engaged in a call, it also monitors the payload channel used for the call. Failures such as lost of frame synchronization can happen. When a failure occurs, the radio may drop the call or perform a possible call handover to continue the call.

The radio remembers the site where it has experienced any failure, and will de-prioritize the site upon site searching.

Call Handover

Capacity Max supports a proprietary call hand over, only for the radios that receive a voice, or are in a call hangtime state in a voice talkgroup call. The transmitting radio does not support call handover. The radio keeps transmitting, when the user with the transmitting radio, moves out of the home site coverage. Upon dekey, the radio ends the call and performs site roaming.

The radio, which is engaged in a voice talkgroup call and works in Capacity Max Open System or Capacity Max Advantage mode, can continue receiving the same call while roaming, with a reduced minimal audio hole. This process is described below.

While in the call, the receiving radio periodically measures the signal strength of its payload channel (the current payload channel). If the signal strength becomes lower than the *RSSI Sampling Threshold*, the radio attempts to roam by starting to sample the adjacent payload channels that carry the same call.

While attempting to roam, upon detecting that the signal conditions for a call handover are fulfilled, the radio performs call handover. If not, the radio continues the call. There are two signal conditions that must be fulfilled, the signal of the current payload channel is lower than the handover threshold value and there is at least one adjacent payload channel that has signal strength more than 6dBm greater than the current payload channel.

A failure in the current payload channel can initiate a call handover too, as long as the above mentioned signal conditions are fulfilled. If not, the radio will drop the call and try to rejoin the call at the same home site.

Manual Site Roam

Manual site roam is a way for the user to force the radio to start site searching, through a button configured as *Manual Site Search*. Upon starting manual site roam, the radio leaves the home site and searches the adjacent sites. Moving away from a site, user may not manually roam back to the original site.

The radio may find any adjacent site, as long as the signal of its active control channel is above the *RSSI Acceptable Threshold*, and the radio has not experienced any failure on the that site before. Manual site roam does not cause the radio to register with an adjacent site that is less favorable than the home site due to any failures. Upon manual site roam, the radio selects an adjacent site based on the site preference level, the signal strength and whether the site is in a site trunking state or not.

Manual site roam is not intended to force the radio to lock to a particular site or register with a particular site. It does not disable automatic roaming too. However, it is useful in combination with the site-locked feature to allow the user to manually control roaming.

The radio prevents manual site roam when it is setting up a call, or when it is engaged in an individual voice call.

Site Locked or Unlocked

Site-locked is a feature to prevent the radio from automatic roaming. Site-unlocked allows the radio to roam automatically. A programmable button can be configured to have a Site Lock On or Off toggle functionality.

When site-locked is switched on, the radio will not automatically roam from its home site, even though communication with the home site cannot be maintained anymore, due to control channel failure or site access failure, or even out of the home site coverage. If it happens, the radio will start site hunting by stepping through all candidate control channels of the home site only, and never of the other sites. This prevents the radio to roam to any other site automatically.

The only way to roam while being site-locked is through a manual site roaming. When the radio roams manually to a new site, it remains in a site-locked condition, but with the new site. The user can further start again manual site roam that causes the radio to roam to another site. After each roaming, the radio remains in a site-locked condition with the respective site which the radio successfully registers with. The user can control when to roam and when not to roam. from site to site, by doing this.

With Site Lock On or Off button, the user can switch off site-locked condition, which means the radio becomes site-unlocked. The radio allows the automatic roaming back in effect, in site-unlocked.

A manual site roam, requested while the radio is site-unlocked, also causes the radio to leave the home site and search for a new home site. The radio may land on a new site that has lower signal strength or even less preferred than the home site, as long as the signal strength is acceptable and no failure has been detected on that site. The radio remains in the new site for a period of time (that is, 2 minutes), and may eventually switches back to the previous home site when the time expires. This is due to the automatic roaming which is still in effect and not prevented by the site-locked feature. An activated site-locked feature can prevent the radio to roam back to the previous home site.

Chapter 17

Capacity Max Radio Registration and Presence Notifier

This chapter describes the types of presence information provided by the Presence Notifier (PN) and how third-party applications connect to the PN and obtain presence information of Capacity Max radios. This section also describes configuration parameters in the PN and criteria for use of a redundant PN.

The PN is a service that enables applications to obtain and track information about the presence of radios. The Trunking Controller on the Capacity Max System Server (CMSS) implements the PN. The trunking controller derives presence and mobility information for a radio from the over-the-air registration by the radio and informs the third-party applications through the PN interface.

Connection of Third-Party Applications to Presence Notifier

The PN provides Transport Control Protocol (TCP) and User Datagram Protocol (UDP) interfaces to third-party applications that require presence information for Capacity Max radios. Applications subscribe for the presence information of radios from the PN, and the PN provides presence and mobility information for the radios to the applications.

- The UDP interface provides one-time query functionality
- The TCP interface provides both one-time query and subscription functionalities.

Presence, Absence, and Mobility Information

The trunking controller derives the following types of information from the over-the-air registration.

Presence

A radio is present in a Capacity Max system when the radio is registered with the system. Registration occurs on the following:

- On power-on
- On roaming to a site
- On changing the personality (that is knob position) from another system to the Capacity Max system
- On changing personality (that is knob position) having a different Tx talkgroup
- When the radio has not received a response for its request within the number of hours configured as the Inactivity Check time.

Absence

A radio is absent in a Capacity Max system when the radio is not registered with the system. De-registration occurs on the following:

- On power-off
- On changing the personality (that is, knob position) from the Capacity Max system to another system
- When the system does not detect any activity from the radio within the number of hours configured as the Inactivity Check time.

When powering off or changing personality, the radio sends a de-registration request over the air. In the event of channel unavailability, lack of time, or poor coverage, de-registration may fail. Enabling or disabling a radio in Subscriber Access Control (SAC) does not change the presence or absence state of the radio.

Mobility

Mobility information of a radio means the RF site where the radio is present and registered. A mobility change notification is sent by the PN to the application when a radio moves from one RF site to another while registered with a radio network.

Subscription and Notification

When an application requires presence information for a radio, it submits a subscription request by sending a subscription message to the PN. This message contains a dialogue identifier (Dialog ID), which is generated and maintained by the subscribing application, as well as the device ID for a radio or a range of device IDs for multiple radios. The PN identifies and maintains each subscription by using the combination of the Dialog ID, the IP address, and the port number of the subscribing application.

The initial subscription message from an application to the PN establishes a “subscription dialog” between the PN and the application. All subsequent communications associated with the same subscription dialog is identified by the same dialog ID. The PN sends an immediate response to the application upon receiving the subscription request. This response acknowledges the subscription request and contains the current presence information of the requested entities in the subscription. As the state or attributes of the presence entities change (for example, radio registration state changed from present to absent), the PN generates notification messages and sends them to all applications with accepted subscriptions for that entity.

The following table lists events that can be subscribed:

Table 6: Subscribed Events

Event Name	Remarks
Present	Application requests Present event
Absent	Application requests Absent event
Mobility Event	Application requests Mobility Update event

Present or absent events and mobility change events can be subscribed to in a single subscription.

An application can conduct a one-time query to fetch the current presence state of presence entities by sending a request message with a new Dialog ID, and with an immediate expiration, that is, a duration value of zero. The UDP interface is used mainly for sending a one-time query. The TCP interface is for both one-time query and subscription.

The subscription persists for a period of time, or duration, that is specified in the initial subscribe message. The subscription can be extended by sending a refresh subscription message with the same Dialog ID prior to the scheduled expiration time. The PN deletes all subscriptions from an application if its connection with the application breaks.

The application can cancel a subscription by sending a subscription message with the same Dialog ID and a zero duration value. This causes an immediate termination of the subscription.

To monitor the health of the network connection to the PN, the application may periodically send a keep-alive message to the PN. The keep-alive message is not associated with subscriptions and can be sent at any time. The keep alive can be sent to the active or inactive PN.

Configuration Parameters for Presence Notifier

Table 7 shows configurable parameters for the Presence Notifier, that are programmed within the Capacity Max System Server (CMSS) through the Radio Management application.

Table 7: Configurable Parameters for Presence Notifier

Configurable Parameters for Presence Notifier	Definition
TCP port, UDP port	Destination ports of Presence Notifier from application point of view.

Presence Notifier Redundancy

An application can register for PN status to determine if the PN is active or inactive. The status of the PN changes from inactive to active when the PN becomes ready to take subscriptions.

The application can register for PN Status with a primary and a secondary PN at the same time but subscribes for radio presence only with the active PN.

- If both the primary and the secondary PN are active, the application should subscribe with the primary PN.
- If the application loses connection with the primary PN and the status of secondary PN is active, the application can subscribe with the secondary PN.

When switching back to the primary PN from the secondary PN, an application should cancel all its subscriptions with the secondary PN.

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Chapter 18

Radio Access Restriction in Capacity Max System

This chapter describes the mechanisms to control access to a Capacity Max system by a radio, a Voice Application, and a Data Gateway. It also provides their use cases and when a mechanism is more effective than the others.

Mechanisms to Restrict Radio Access to Capacity Max System

Capacity Max provides three mechanisms to restrict a radio's access. The mechanisms are as follows:

Authentication

The infrastructure authenticates a radio to ensure that the radio is what the radio claims to be. This mechanism is useful to restrict the services of a Capacity Max system to only the radios that belong to the system owner. Authentication prevents others from stealing the radio services. Authentication is performed during every registration process of the radio. If the authentication fails, then the radio is not registered. Therefore, any service request from the radio user is denied both by the radio and the infrastructure. The required parameters for authentication are configured in the radios and the repeaters by the Radio Management. See Authentication on page 62.

Subscriber Access Control (SAC)

Through its Radio Management, a Capacity Max system allows maintaining a list of permitted services and a list of permitted sites for each radio in the system. When a radio sends a service request, the infrastructure can deny the request if the service is not in the list of permitted services. Similarly, when roaming to a site, the infrastructure does not register the radio if the site is not in the list of permitted sites. SAC also allows to disable (and enable) all the services to a radio. SAC is useful for restricting the services temporarily for a radio (for example, service is blocked due to non-payment of dues). The SAC also allows the system owner to charge for services based on the type of services, number of sites, or both. It can be utilized for dynamic changes the capabilities of a radio without reprogramming the radio. See Subscriber Access Control on page 63.

NOTICE: SAC restrictions are only applicable to authenticated (or registered, if authentication is disabled) radios. Without authentication, it is not very useful in preventing others from stealing the radio services because the ID of a radio can be changed using Radio Management.

Stun/Revive

A Voice Application can deny a radio the access to services by sending an Over-The-Air command to the radio. A stunned radio does not request or receive any user-initiated services on a Capacity Max system, where it was stunned. However, a stunned radio does roam from one site to another, register, authenticate (if required), and execute a received revive command. A stunned radio continues to send the location updates, receive location request, and can be remotely monitored.

NOTICE: Stunning a radio on a system does not change the radio's behavior on other system. Stun is a system wide and not a radio wide.

Disabling a radio using SAC and stunning a radio has a very similar effect. The radio cannot initiate or receive a call. The main advantage of Stun is that the radio continues to send location updates and therefore a lost radio can be tracked. Another main advantage of Stun is the radio's access to the

system is disabled immediately. The main disadvantage of Stun is that a radio can be stunned only if the radio is powered on and is in coverage area of the system. See Stun/Revive on page 64.

Authentication

This section describes the disadvantages of using the authentication feature, the use of a Mater Key in Capacity Max to simplify Key Management when using the authentication mechanism, as well as the use of enhanced version of the authentication process of the DMR Tier III standard in Capacity Max system.

Authentication as an Optional Configuration Setting

The authentication of a radio by the infrastructure or the authentication of the infrastructure by a radio (during Stun/Revive) uses a “Challenge and Response” process. A disadvantage of the process is that it requires additional Over-The-Air messaging between the radio and the infrastructure. This reduces the inbound (for example, service initiation) capacity of the control channel.

For this reason, Capacity Max has a configurable system-wide parameter to disable and enable the authentication feature and a second slot registration. MOTOTRBO radios prefer to do registration (and authentication) on the second slot of the control channel; and therefore, enabling authentication on a Capacity Max system having MOTOTRBO radios do not reduce the service initiation capacity. It reduces the registration capacity only.

User must configure the parameter in all Control channel-capable repeaters. Any change in the parameter values is effective only after reprogramming all the control channel repeaters.

NOTICE: Reprogramming causes the repeater to reset.

Master Key for Simplified Key Management

Authentication relies on a 128-bit long key that is shared between an individual radio and the infrastructure. If a same authentication key is programmed into each radio, then the compromise of one radio affects the entire system. Alternatively, configuring a different key for each radio makes the key management difficult. Therefore, Capacity Max uses a system-wide Master Key configured by the system owner using Radio Management. The Radio Management derives a unique key for a radio using a one-way function and provisions it into the radio, if the radio is a MOTOTRBO radio. For a non-MOTOTRBO radio in a Capacity Max system, the key derived by the MOTOTRBO’s Radio Management should be configured in the non-MOTOTRBO radio using its configuration tool.

The one-way function makes obtaining the Master key from a derived key difficult. The radio uses its derived key to provide the response for the challenge during the authentication process. The infrastructure calculates the unique derived key in the same way as the Radio Management, and uses the derived key to verify the response received from the radio. The main advantage of the Master key is that the owner and the system need to manage only one key for the authentication of all the radios.

The security of the “Authentication” rests in the key. Key management is the weakest part of the security. It is easier to use flaws in people to obtain the key, than breaking the authentication algorithm. Key value must be as random as possible, preferably generated by a reliable random source (including rolling a die, roulette wheels, or lottery machines).

Physical Serial Number as Enhanced Authentication Mechanism

In a Capacity Max system, both the MOTOTRBO radio and the infrastructure use the Physical Serial Number (PSN) of the radio to calculate the response for the challenge generated by the infrastructure. This implies that an authentication is successful only if the radio has the right derived key and the same PSN as configured by the system owner in the infrastructure.

Without the above enhancement, on the loss of a radio, the system owner can disable the radio in SAC. Disabling the radio in SAC prevents someone from stealing the services using the lost radio.

However, disabling the radio prohibits the owner from re-using the ID of the lost radio, resulting in Address Book changes in many radios.

This enhancement allows the system owner to replace the lost radio with another radio by replacing the PSN of the lost radio with the PSN of the replacement radio.

NOTICE: The replacement radio is configured with the ID of the lost radio. If zero is configured as the PSN for non-MOTOTRBO radios in the infrastructure, the enhancement is transparent for non-MOTOTRBO radios.

Subscriber Access Control

This section describes the ways a system owner can control the services a radio can use in a Capacity Max system.

A system owner can individually disable or enable the following services for each radio, Voice Application and MNIS Data Gateways:

Table 8: Radio Services

Call Initiation Capability	Call Reception Capability
Group Data Call	Individual Voice Call
Individual Data Call	Stun/Revive
Group Voice Call	Remote Monitor
Broadcast Voice Call	Individual Telephone Call
Individual Voice Call	
Multi-site Voice All Call	
Site-wide Voice All Call	
Telephone Call	
Emergency Call	
Remote Monitor	
Short Data Call (*DMR Short Text*)	
Stun/Revive	
Call Alert	
Remote Monitor	
Radio Check	
Voice Interrupt	
Stun/Revive	

NOTICE: At least one Radio ID is associated with a Voice Application or a MNIS Data Gateway. Not all the above listed capabilities are applicable to a Gateway. For example, a Gateway cannot be stunned or a MNIS Data Gateway cannot use the voice services.

Capacity Max allows a System Owner to Control the Sites where a Radio can Avail the Services

A Capacity Max system allows a radio to register only at the specified sites. Therefore, the radio can initiate or receive a call at the specified sites only.

Stun/Revive

This section describes the Stun/Revive command supported in the Capacity Max system.

A radio cannot initiate Stun/Revive. Only a Console/application connected to a gateway can initiate Stun/Revive. Capacity Max infrastructure executes the Stun and Revive procedures on the control channel. The target radio must be on the control channel and be within RF range for this action to be completed successfully. The Capacity Max system supports Stun/Revive with or without Authentication.

When Stun/Revive authentication option is enabled, on reception of Stun/Revive command, the radio authenticates the system by sending a Challenge, receiving a response and validating the response before executing the command. The authentication Key used for Stun/Revive of a radio is the same Key used for the authentication of the radio during registration.

A radio is denied access to all user-initiated services for the system on which it was stunned. However, roaming, registration, authentication, stun/revive services remain active. The radio can be remotely monitored, and continues to send the location updates while stunned. The radio can also receive new LRRP requests while stunned.

A radio can be revived by doing the following:

- Either sending (Over-The-Air) a “Revive” command to the radio
- Reprogramming the radio over USB connection using Radio Management

NOTICE: The radio cannot be revived by power cycling or by Over-The-Air Programming (OTAP).

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Chapter 19

Capacity Max System Advisor

This chapter describes the architecture and features provided by the System Advisor. System Advisor is a Capacity Max application that helps the system maintainers to manage their systems easily, quickly diagnose the problems with the infrastructure devices and monitor the call activity in the system, all from one centralized location.

Overview

The System Advisor is an application that provides fault management and system and call monitoring solutions for Capacity Max Systems. It helps the system maintainers to manage their systems providing centralized way to view the system health, detailed information about the status of the infrastructure devices, perform simple operations on the devices remotely, and view the call activity and the channel usage. The System Advisor manages infrastructure devices through several of protocols, including SNMPv1, SNMPv3, ICMP and web-services.

The System Advisor consists of client and server application.

- The server application runs on Capacity Max System Server (CMSS) logically located at the system level, outside of RF sites.
- The client application is a Java Web Start application that can be run on Windows based PC that has access to the CMSS server (radio IP network). Client application requires Oracle Java to be installed on the PC and a web browser.

The basic functionality of the System Advisor is enabled with the Capacity Max System Advisor license. Optional functionality can be enabled through additional licenses.

The following are the main functions of the System Advisor:

System View

System View provides hierarchical view of System Advisor Network Database and groups the site level devices under Site objects and system level devices under a System object. Status is propagated upward from each device to provide an “at-a-glance” view of the system health. The user can quickly navigate to the other views such as Alarm, Event or Network Database view, that show the additional information for the selected element.

Real Time Call Monitoring

System Advisor provides two views that show real time call activities, as follows:

- Grid View

It shows the list of sites with available channels and the use of slot on the channels. User is able to see the transmissions happening on the channels, call types, channel types, and fault state of the channels, where it is fault state of the repeater hosting the channel.

- Raw View

It shows the list of calls and decoded events as received by System Advisor. View shows calls that are in queue, active, ended, and the associated events. Other events which are not related to calls, are also shown.

Both views provide simple customizing and filtering capabilities.

North Bound Interface

System Advisor receives events from the managed network devices, processes them, correlates events to alarms and presents them to the operator. System Advisor additionally supports a North Bound Interface (NBI) to send all these events to North Bound Managers like Network Management Systems or Manager of Managers (this can be any Motorola or third party application capable to receive and process System Advisor NBI notifications). The documentation that includes specifications of the interface is provided by the Motorola ADP team. The interface includes notification of network events and management events to the registered managers as follows:

- Network events

The network events are the events originated at the device level or the System Advisor regarding certain network behavior. For example, if a network switch reports to the System Advisor that some of its Ethernet port is down, such event will be sent to the registered NBI clients.

- Management events

The management events are events originated at the System Advisor as a result of management operations performed on System Advisor like synchronization, discovery, manage / un-manage a device, and others. For example, if the new device is discovered by the System Advisor, an event if the discovery operation was successful is generated to the NBI clients.

The North Bound Interface supports both clear and secure capability of sending the notifications (SNMP Traps) over SNMPv3 protocol. Its functionality requires North Bound Interface license to be purchased by the customer. If the NBI license is purchased, up to two NBI destinations (managers) can be registered using System Advisor client application.

Discovery and Network Database

Discovery is the process of adding an individual device or all the devices at a system into the System Advisor database. System Advisor supports automatic triggering of discovery process for devices reported by the system as well as manual discovery of the device after user provides necessary parameters like the IP address and SNMP port.

In System Advisor application, the network database view serves as an inventory of the network resources. It maintains the properties of all the managed resources, including both physical devices (for example, the Repeater) and logical entities (for example, the Site, System, and Network) entities discovered by System Advisor.

A user can invoke operations on inventory items such as command, manage / un-manage, synchronization, ping, trace route, and others.

System Advisor manages and presents information about the following devices in Capacity Max system:

- Repeaters
- Trunk Controllers
- Capacity Max System Servers
- System Advisors
- Voice Gateways (along with information about connected clients)
- Data Gateways (along with information about connected clients)
- Network Switches and Routers (MSI recommended)
- Manually discover other devices. System Advisor manages them, depending on how they are recognized by the System Advisor and what management protocols they support.

Device Synchronization

Device Synchronization is defined as the basic mechanism that allows System Advisor to determine and refresh information about the status of the managed devices. The synchronization process performs periodic SNMP query on each device that is in “managed” state. When the user may not want to receive updates about the state of some particular devices, the device may be moved by the user to “un-managed” and synchronization process will omit such device.

Communication Link Management

Communication Link Management is defined as the basic mechanism for the System Advisor to detect communication loss between itself and a particular managed device. Whenever a communication loss is detected, the System Advisor will generate a communication loss alarm in the alarm browser. In order for Communication Link Management to function, the device must be currently managed by System Advisor..

Command Operation

The System Advisor provides command operation for repeater devices. The following commands are supported:

- Enable, Disable, and Reset

Change the operational state of the repeater.

- Read of Repeater Remote Diagnostic counters

Gather the repeater diagnostic information and store it in log file for further analysis.

- Reset Repeater Remote Diagnostic counters

Reset the counters to initial value.

Network Events

Network event is the basic unit of management information that represents what has happened to a particular managed device. Event can convey from general information such as discovery of a device, to a specific type of information such as failure of a managed entity or status update of a managed entity. Events form a repository of information for all the occurrences in the system. The System Advisor event view provides a way to look at all events or a filtered subset of events, that are received or generated by System Advisor.

User can view the details of each event, export them to cvs file or define custom views, to view a filtered subset of events as well (for example, view only critical events that are from a particular device type and / or from a certain site).

Alarms

In System Advisor, an alarm results from an event in a managed device that met a pre-determined significant state change that may require user attention. The System Advisor alarm browser view provides a way to look at all alarms, or a filtered subset of alarms. An audible tone can be associated with alarms, based on severity.

An alarm becomes active once the System Advisor displays the alarm in the alarm view, without clearing it. System Advisor will clear the alarm, whenever the problem that caused the alarm of a particular managed device to be elevated in System Advisor is resolved. User with an administrator privileges can set an Alarm Clear Timer policy, allowing the cleared alarms to persist in the System Advisor alarm view, from 15 minutes to 10 hours, in 15 minutes increments.

The user can enter any additional information in a text field, and assign an alarm to a user. A user can view the alarm details, export the alarms to csv file for future analysis and define custom views, to view a filtered subset of alarms.

Chapter 20

Capacity Max Radio Management

This chapter describes the devices in the system configured within Radio Management, the advantages of centralizing all configurations, how the system parameters and device configuration sets simplifies the configuration process, and the various configuration delivery options that Radio Management supports.

Overview

Radio Management (RM) allows the administrator to configure, manage and program the subscribers and infrastructure in a Capacity Max system. The following Capacity Max devices are configured with Radio Management:

- Trunking Controller
- Repeaters
- Subscribers
- MNIS VRC Gateway
- MNIS Data Gateway

Radio Management is a required application for a Capacity Max system. It can be installed on any computer that meets the minimum hardware and software requirements and that has a direct IP connection to the Capacity Max system. The computer specifications are identified in another section.

Radio Management consists of a four major components that can be installed on the same or different computers. The components include the Radio Management Server, the Radio Management Client, the Radio Management Job Processor, and the Radio Management Device Programmer. The Radio Management Job Processor is usually installed on the same computer as the Radio Management Server.

The device configurations are saved centrally in the Radio Management Server, and can be accessed remotely by the Radio Management Client. The Radio Management Device Programmer communicates with the system and can be remote from the Radio Management Server to allow flexible deployments. Reading and writing codeplug files with an unmanaged CPS is not supported in Capacity Max.

Advantages of Radio Management

This section describes the advantages of Radio Management. The following are some advantages of Radio Management:

Centrally Saved Configurations

Saving the configurations in the Radio Management Server allows all configurations to be centrally managed. This removes the need to handle numerous codeplug files for every device in the system. Centrally managing all the configurations in one database can:

- Simplify inventory by searching, sorting, and grouping radios in one place
- Simplify configuration by sharing device templates configuration sets and system parameter sets
- Simplify management of unique identifiers by cross referencing the configurations

System Level Configuration

All devices in a Capacity Max system reference the same system level parameters. This minimizes entering duplicate information for each device type, therefore lowers the probability of mistakes. Examples of system level parameters are trunking controller IP, site information, channel information, and site adjacency information.

Subscriber Access Control

The subscriber access control (SAC) is configured within Radio Management. The SAC is where the subscriber access to the system and the features allowed by that subscriber, are centrally controlled. This information is programmed into the Trunking Controller.

Talkgroup to Site Association

The talkgroup to site is configured within Radio Management. The talkgroup to site association controls which sites a talkgroup should always be routed to regardless of affiliation, and which sites a talkgroup is specifically not allowed at. This information is programmed into the Trunking Controller.

Device Configuration Sets

Device Configuration sets can be shared across multiple devices of the same type, so that changes are automatically applied to all devices using the shared configuration sets. This minimizes entering duplicate information for each device, therefore lowers the probability of mistakes. This is most useful for managing radio configurations of various groups within an organization.

Radio and Repeater Firmware Upgrades

Radio and repeater firmware are upgraded within Radio Management. The Trunking Controller, Voice and Data Gateway, and System Advisor are not upgraded from within Radio Management. They utilize a separate utility named ESU (Enhanced Software Updater).

Scheduled Batch Configurations

Numerous devices can be selected and their programming can be scheduled for a specific time. When the scheduled devices become present after their scheduled time, their new programming is delivered. This is extremely useful when programming numerous radios with different configuration sets and unique identifiers.

Radio Management Programming Options

Radio Management provides numerous programming options, which include:

Direct USB Programming

Radio and repeaters can be programmed via a direct USB connection to the Radio Management device programmer. This is required for the initial programming of these devices. Programming includes configuration, firmware, feature activation, and device resources like the language packs, voice packs, and others.

Over the IP Network Programming

The Trunking Controller, Voice Gateway, and System Advisor Server are configured via a direct IP network connection with the Radio Management device programmer. After the initial programming, repeaters are programmed over the IP network.

A Radio Management device programmer can be remote from the Radio Management server via a direct IP network connection. Therefore, numerous device programmer computers can be strategically located within the customer’s organization. The users need to plug their radios into a device

programmer computer via USB, and if previously scheduled will trigger the configuration to be delivered and firmware to be upgraded.

Over the Air via Wi-Fi® Programming

Radio Management can program radios over Wi-Fi®. Programming includes configuration, firmware, feature activation, and device resources like the language packs, voice packs, and others. Selected radio models have Wi-Fi enabled from the factory. They are pre-configured with a default access point profile (SSID and WPA/WPA2 passphrase).

When the radio initially powers up 'out of the box', it connects to an access point with the default SSID and passphrase, and acquires an IP via DHCP. If a Radio Management device programmer is on the same IP network, the radio becomes present to the device programmer. If there are any scheduled jobs for the radio, they are delivered to the radio over Wi-Fi.

The radios are required to be added into Radio Management with their specific serial number, which can be acquired from the invoice. A job should be scheduled, upon unique system identifiers, firmware, device resources, and configuration sets are assigned.

Over the Air via the Radio System Programming

Radio Management can perform over the air programming on the radio system, once a Data Gateway is configured and all subscribers are initially configured via USB or Wi-Fi and can communicate on the radio system. When the devices scheduled become present on the system after their scheduled time, their configurations are delivered. Since bandwidth is limited on the radio system, this process may take a while. Firmware upgrade, feature activation, and device resources like language packs, voice packs, and others are not supported over the air on the radio system.

When additional sites and channels are added, Radio Management can broadcast this information over the air to the radios. The information is announced over the control channel of the existing sites for a specified duration. This broadcasted method is quicker than individually scheduling each radio.

Over the Air via Bluetooth Programming

Radio Management can program radios over Bluetooth programming, which includes configuration, firmware, feature activation, and device resources like (language packs, voice packs, and others. Selected radio models have Bluetooth capability. The radio must be paired with the computer, where the Radio Management device programmer resides. Programming over Bluetooth is best utilized when other programming options are unavailable and access to the radio's programming port is obscured. This often happens, when programming a radio installed in-vehicle.

Off-Line Mode Programming

Radio Management can program radios, where the device programmer does not have an IP network connection to the Radio Management server. This is often referred to as off-line mode. This is useful when there is no IP network connectivity at the location, where the radios or repeaters reside. While connected to the IP network, scheduled jobs can be selected and downloaded at the device programmer. When disconnected, and the radios or repeaters become present (USB, Wi-Fi, and others), the device programmer programs them. Once the device programmer is re-connected to the IP network, it reports the device status back to the Radio Management server.

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Chapter 21

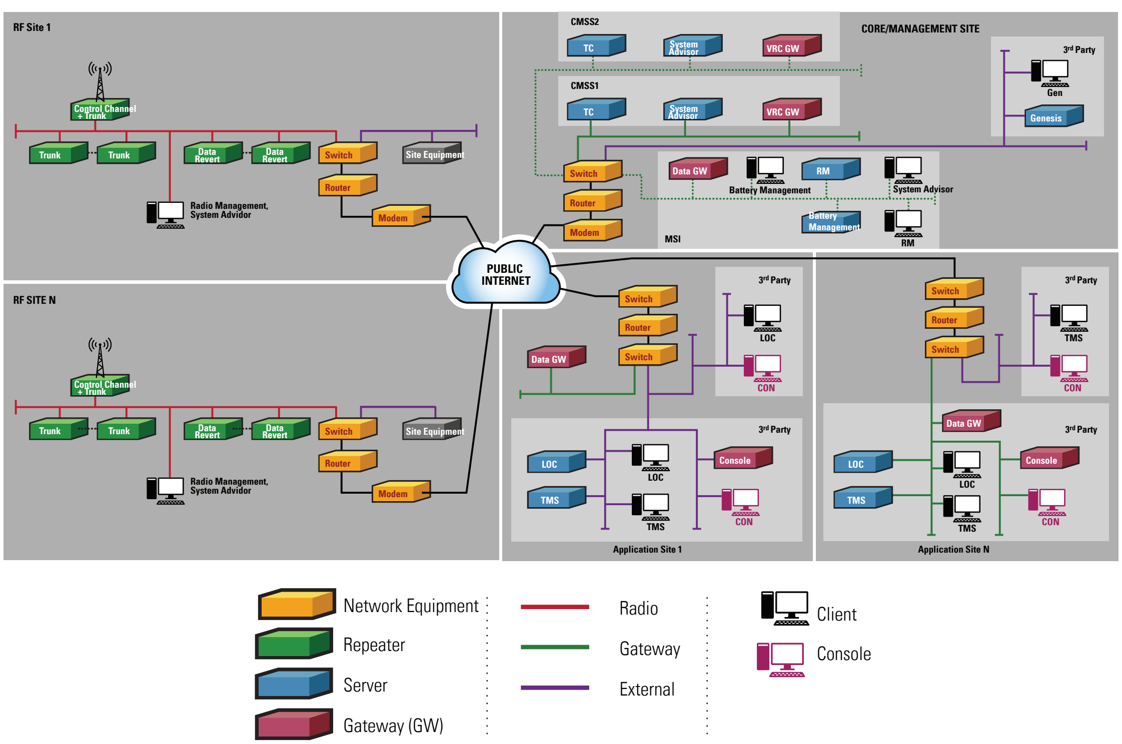
Capacity Max Architecture and Configurations

This chapter identifies the entities of a Capacity Max system, and describes some of the possible topologies.

Overview

The following figure shows an example of the Capacity Max system configuration. It consists of two RF sites, one management site, and two application sites. A RF site has one or more trunk repeaters, zero or more data revert repeaters, and optionally clients of management applications such as radio management, and system advisor. A RF site may also have some other site equipment such as power monitor. A management site has Capacity Max servers, Motorola supplied system management applications (for example, radio management and battery management), and third party supplied system management applications (for example, GW3–TRBO from Genesis). An application site has data applications (for example, location server and Text message server), which interface with a MNIS Data Gateway. It may also have voice applications (for example, console, voice recorder, and phone gateway), which interface with a MNIS VRC Gateway. All the above mentioned entities communicate over the IPv4 based network. The following sub-sections briefly describe the entities of a Capacity Max system.

Figure 1: Capacity Max System Configuration



Communication Network

The communication network of a Capacity Max system consists of a set of IPv4 based local networks (one per site), and an IPv4 based back-end network that connects all the local networks.

The local network is used for intra site communication between entities at a site. All Capacity Max repeaters at a RF site are connected over a LAN, and they must be in the same IP subnet. Two or more RF sites do not share a subnet and a RF site, and a RF site do not share a subnet with a voice or data gateway.

The back-end network is used for communication between sites and with the Application Servers. Capacity Max supports a wide variety of back-end networks, from a dedicated network to an Internet provided by an Internet service provider (ISP). The back-end network of Capacity Max should **not** be based on “dial-up” connection due to small bandwidth, or Satellite Internet access due to large delay.

The types of connection between the LANs and the back-end network results in multiple network topologies. The following network topologies are supported by a Capacity Max system:

- Native Private Network

In a Native Private Network, all the entities over the LANs and back-end network are in the same private network. The IP addresses over all the LANs are in the IP address space of the back-end network. Thus, the customer determines the IP addresses and subnets that the Capacity Max system can use.

- Virtual Private Network

In a Virtual Private Network, the private networks of sites are tunneled across the public network of the back-end to form a single private network. The IP addresses over all the LANs are in the same IP address space, but the IP addresses over the back-end network are in a different address space. It enables entities to send and receive data across shared or public networks, as if it is directly connected over a private network. A Virtual Private Network is created by establishing a virtual site-to-site connection through the use of either dedicated connections or virtual tunneling protocols. The Capacity Max primary use case employs a router with site to site VPN. When a VPN is being used, all external applications like the servers and clients must reside in the same VPN, as the core radio and gateway equipment. The clients can be outside of VPN, if static NAT is configured in the routers or a remote access VPN solution is installed.

In certain circumstances, the private networks of sites are connected together by mapping every address in use in a private network, to a corresponding address in the public network of the bac-kend. This is often accomplished by Network Address Translation implemented in a routing device. The IP addresses of all the LANs are in different IP address spaces, but they are mapped to a common the IP address space of the back-end network. A Capacity Max system does not support this configuration.

Figure 1 shows, the entities are segregated amongst three basic network types (Radio Infrastructure, Gateway and Application), which reside on various Virtual LANs or VLANs. This type of segmentation is required at most physical locations. It is dependent upon physical location of equipment and is accomplished with 802.1q VLAN tagging. The following rules apply, when determining required VLAN segregation at a physical location:

- Co-located RF sites must reside on separate Radio Network subnets.
- Co-located Capacity Max Servers (CMSS) must reside on separate Gateway Network subnets.
- Co-located MNIS VRC Gateways must reside on separate Gateway Network subnets.
- Co-located MNIS Data Gateways must reside on separate Gateway Network subnets.
- Any of these four (RF sites, CMSS, MNIS VRC gateways, and MNIS Data Gateways) must reside on separate subnets from each other.

Sites

A site is a physical location, where a set of repeaters, servers or PCs are connected over a LAN. There is an exception to this, where a physical location may have two or more virtual LANs. In that case, each virtual LAN is a site.

A RF site supports one or more frequency pairs, where each frequency pair supports two Over-The-Air (OTA) communication paths, that is logical channels.

All the frequencies used at a site must be within the band(s) supported by the radios that intend to operate at the site. This implies that all the sites where a radio can roam should have the frequencies from the same band(s). Since, MOTOTRBO radios support both 800 and 900 MHz bands, a site can have frequency pairs from both the bands. A Capacity Max system can have sites from different bands.

An OTA communication path is used as a control channel, a trunked channel (used for voice or data), or a data revert channel. A RF site can have one to four candidate control channels. In Capacity Max, a control channel is always the first slot of a frequency pair. The frequency pairs of the candidates control channels are dedicated (that is, not shared with any other system).

For a talkgroup call, a site can have only one inbound communication path (Over-The-Air and Over-The-Wire) active at a time. This implies that two MNIS VRC Gateways cannot be on the same LAN, and a MNIS VRC Gateway cannot be on the LAN having repeaters.

Gateways

Capacity Max offers a MNIS Data Gateway, which acts as a gateway for data messages exchanged between radios and data applications (for example, the location server, text message server, radio management, and battery management). A MNIS Data Gateway is recommended at a site where a data application is present.

In lieu of a MNIS Data Gateway, a control station can be used to receive data messages over a revert channel. This will require one conventional control station per data revert channel for each site; because a Capacity Max system does not support wide-area data revert channels. If control stations are required to receive over payload channels (trunked), then the control station should be a Capacity Max radio.

NOTICE: Capacity Max system does not encourage interfacing data applications through control stations.

Capacity Max system also offers a MNIS VRC Gateway, which provides interface for consoles, voice recorders, and telephone to participate in voice calls.

Servers

A Capacity Max System Server (CMSS) is a computing platform where one or more system applications such as the trunking controller, system advisor, and VRC gateway run.

NOTICE: A data gateway does not run on a CMSS, but on its own server. A dealer is not allowed to put applications on a CMSS. The applications should run on their own servers.

The main function of a trunking controller is to allocate resources (for example, channels and gateways) to calls in an efficient way. The trunking controller also provides the presence information of radios to data applications, and performs access control and authentication of radios. The system advisor, which follows a client-server model, is responsible for the following:

- Displaying and logging alarms/events/status of repeaters and gateways
- Displaying and logging call information from repeaters and gateways
- Performing control operations on repeaters

Deployment of Topologies

This section briefly explains some deployment topologies, a representative subset as to provide guidance.

NOTICE: All of the lighter colored boxes in the diagrams represent a physical machine.

For deployments of data applications, the two most common deployments are with the MNIS Data Gateway on the same server as data application, and with the MNIS Data Gateway on a different server as the data servers and clients. The following are recommended with respect to the network type, if there is only one NIC per the data gateway machine:

- Servers and clients (Motorola or third party) on a machine with the data gateway reside on the Gateway Network.
- Motorola servers and clients not on a machine with the data gateway reside on the Gateway Network.
- Third party servers and clients not on a machine with the data gateway reside on the Application Network.

Figure 2 shows the Capacity Max system topology, where two RF sites are co-located and sharing the same router. In this scenario, the two RF sites should be on two different VLANs.

Figure 2: Two RF sites are co-located in Capacity Max System Topology

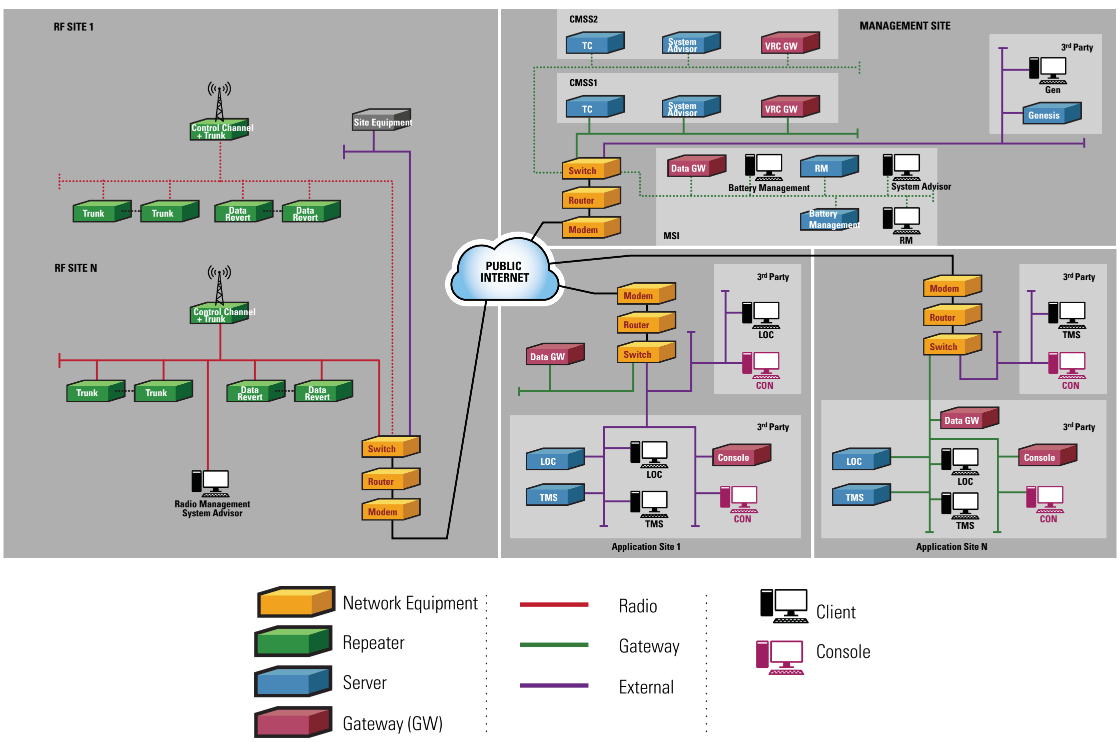


Figure 3 shows the Capacity Max system topology, where the core site (that is the Capacity Max System Server) is co-located with a RF site. In this scenario, the core site and the RF site should be on two different VLANs.

Figure 3: Core Site is co-located with a RF Site in Capacity Max System Topology

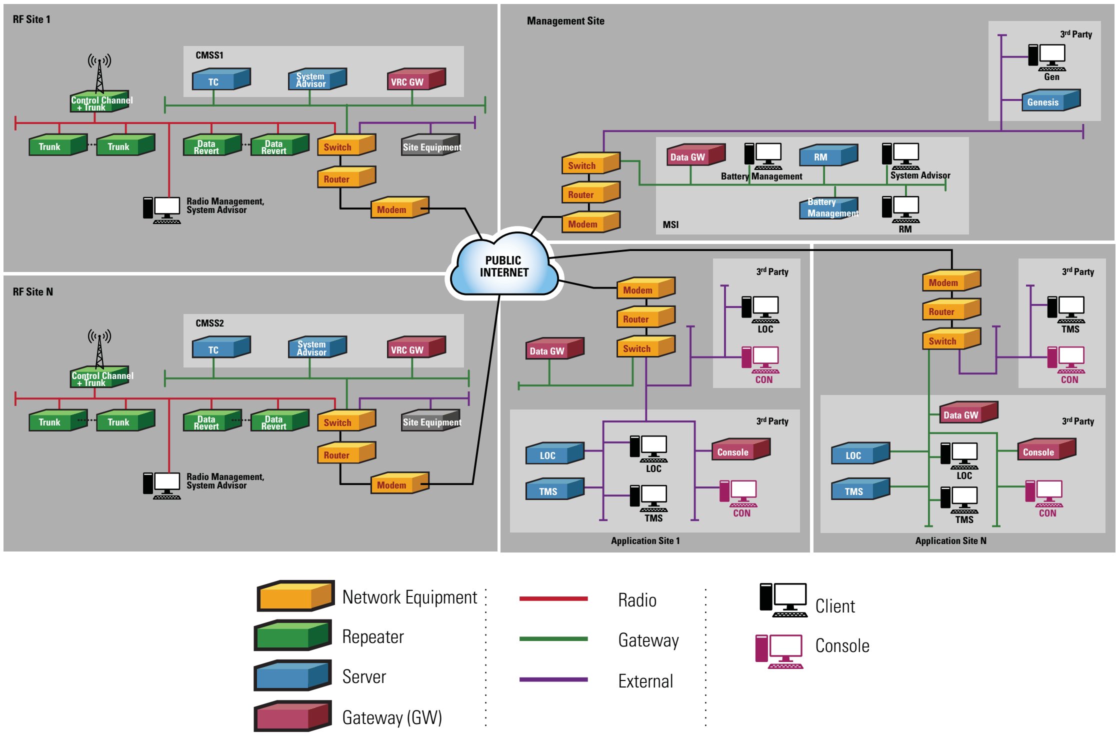


Figure 4 shows the Capacity Max system topology, where the core site (that is the Capacity Max System Server) and the management sites, are co-located with a RF site.

Figure 4: Core and Management Sites are co-located with a RF Site in Capacity Max System Topology

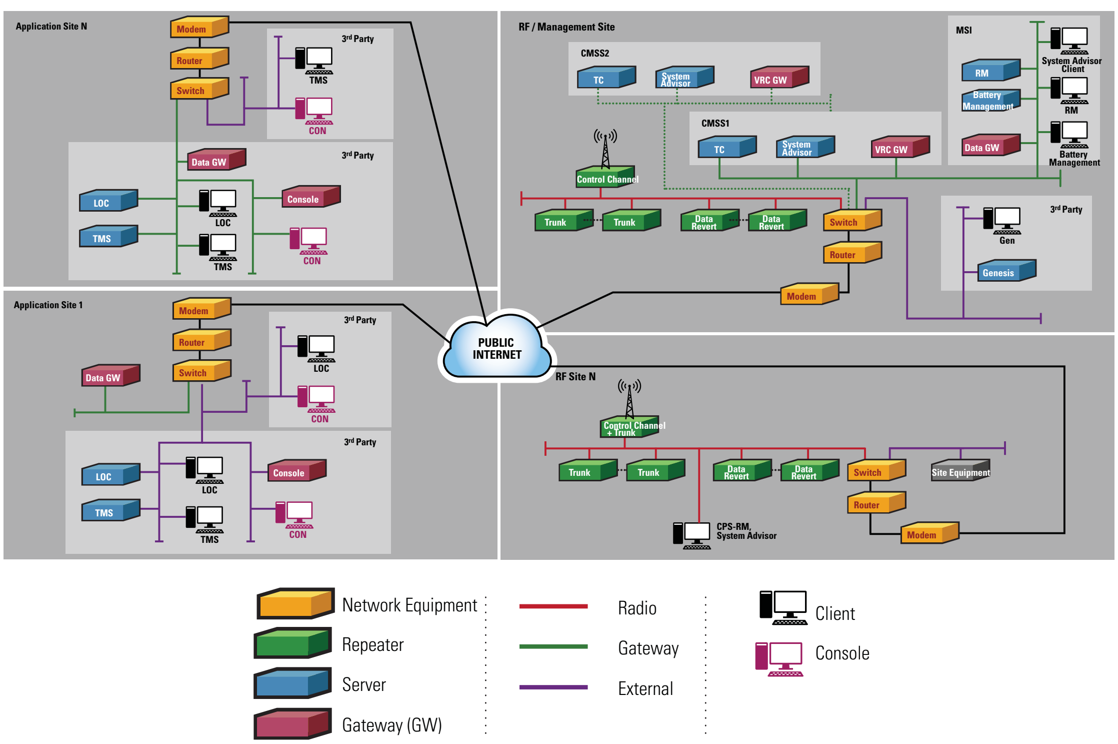


Figure 5 shows the single site Capacity Max system topology, where all the entities are at the same location.

Figure 5: Single Site Capacity Max System Topology

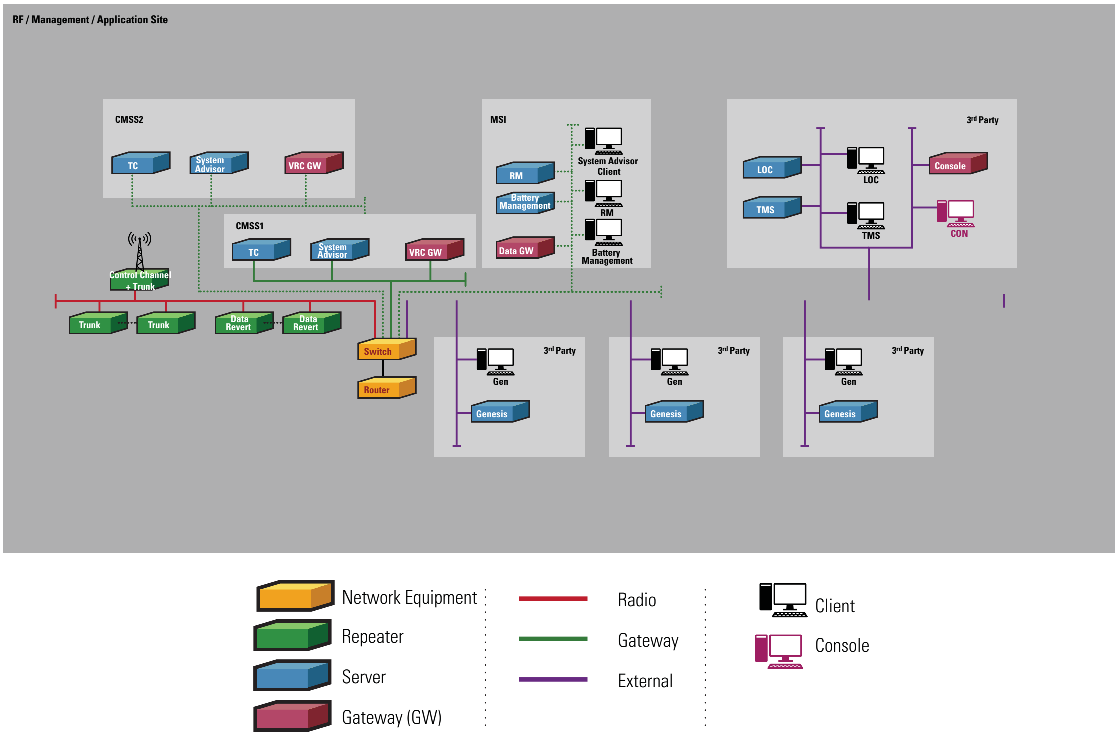


Figure 6 shows the Capacity Max system topology, where the RF sites, the core site (that is the Capacity Max System Server), and the application sites are in the customer network.

NOTICE: The network equipments at the Management Site and the connectivity are not specified in the diagram. Customers can reach to their IT department to find an acceptable solution. It might be a VPN between the management site and core site, a remote access VPN built up on demand, or others.

Figure 6: RF, Core and Application Sites at Customer Network in Capacity Max System Topology

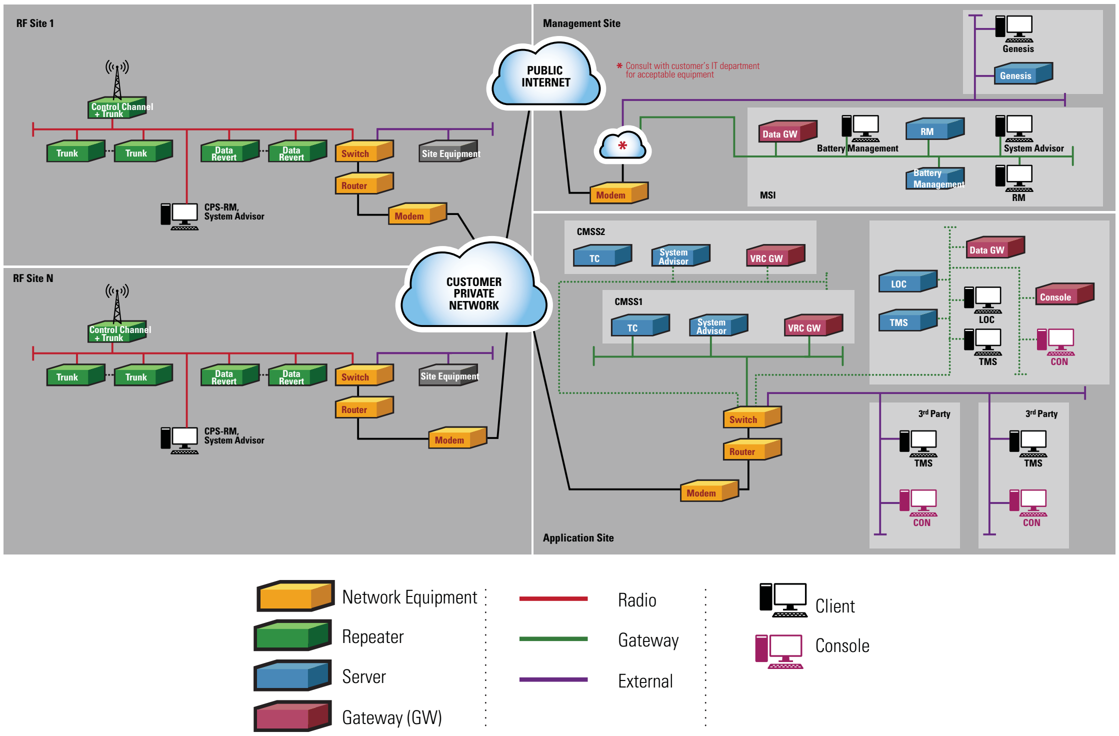
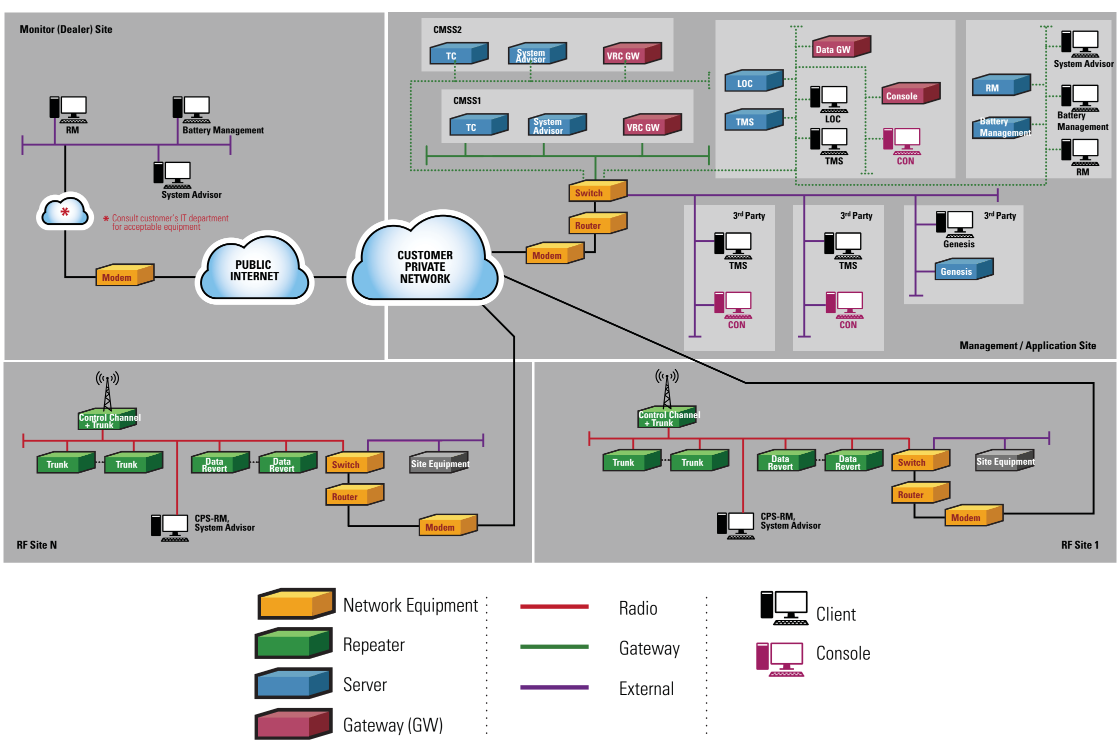


Figure 7 shows the Capacity Max system topology, where the RF sites, the core site (that is the Capacity Max System Server), the management site, and the application sites are in the customer network.

Figure 7: RF, Core, Management and Applications Sites at Customer Network in Capacity Max System Topology



NOTICE: The network equipments at the Monitor Site and the connectivity are not specified in the diagram. Customers can reach to their IT department to find an acceptable solution. It might be a VPN between the management site and core site, a remote access VPN built up on demand, or others

Part II

System Planning

This section describes the Capacity Max System planning.

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Chapter 1

Capacity Max System Planning

This chapter summarizes a high level Capacity Max system planning, and identifies the major planning steps to follow prior to ordering the system.

Overview

The following are some mandatory hardware and software requirements that must be fulfilled in order to deploy a basic Capacity Max system. A Capacity Max system must have at least:

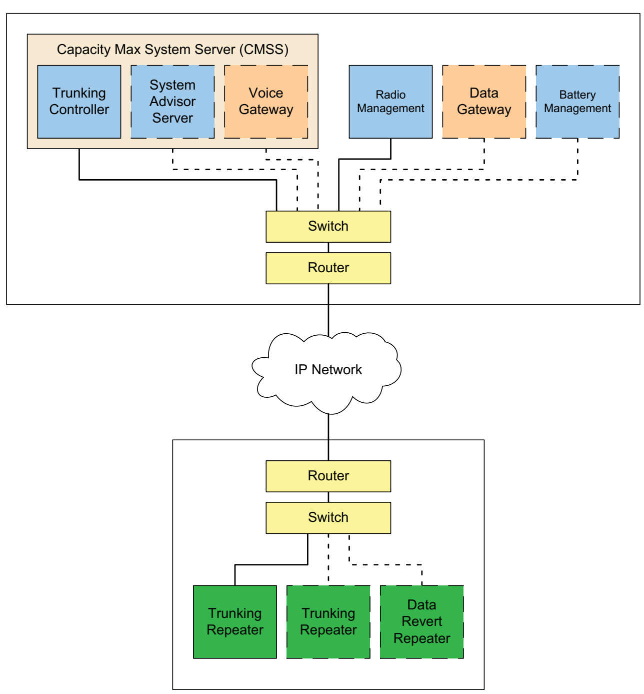
- A CMSS (Capacity Max System Server), with a licensed Trunking Controller
- One RF site with at least one trunking repeater, with a Capacity Max system license
- The Radio Management application to program the equipment
- The switches and routers to connect the equipment within the site or sites where the CMSS, repeaters, and Radio Management are located
- Radios for the end users

Additional RF sites can be added for wider area operations and additional trunking repeaters can be added at sites to support more users per site. Data Revert repeaters can be added to sites when higher location update rates are required and/or to offload the data load from the trunking repeaters. When more than one RF site is in the system, a Capacity Max Site license is required for each additional site beyond the first. The additional Data Revert repeaters will also require Capacity Max system license.

The System Advisor can be optionally added to monitor call activity and equipment status. MNIS VRC Gateways and MNIS Data Gateways can be added to support wire-line voice and data applications.

Redundancy options are also available for both the hardware and the associated software licenses.

Figure 8: A Typical Capacity Max System



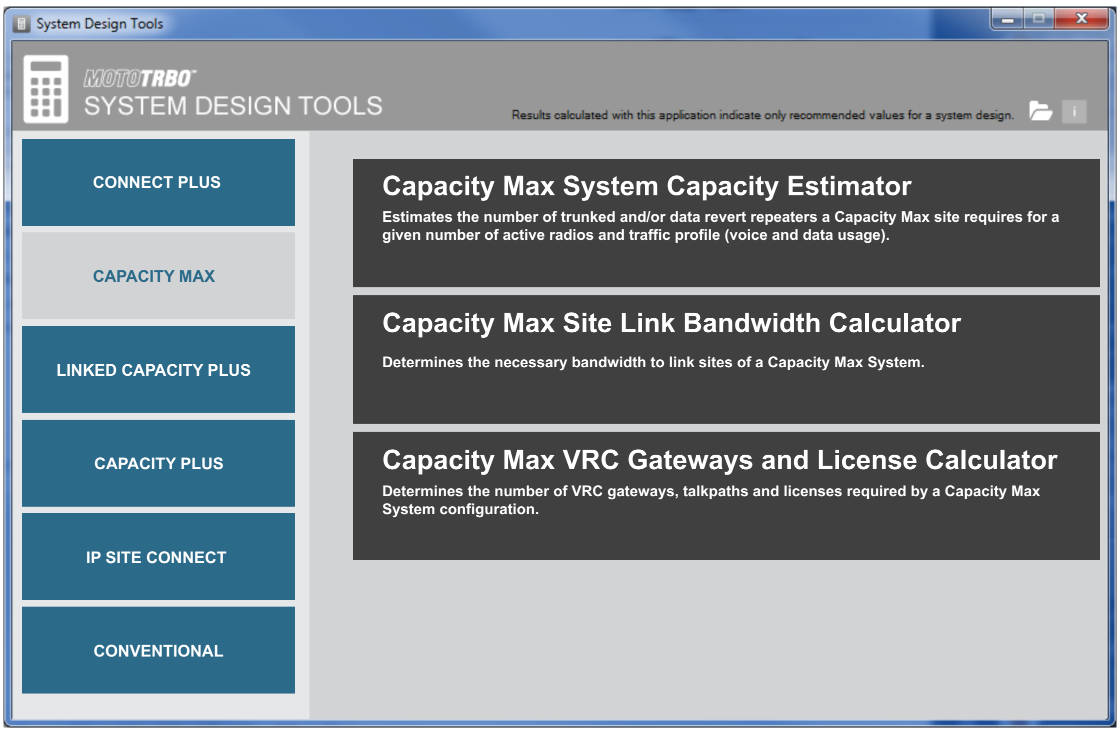
High Level System Planning

The following sections describe a high level summary of how to go about planning for a Capacity Max system.

The MOTOTRBO SDT (System Design Tools) can be used to calculate the number of CMSSs and all Capacity Max licenses when a detailed system planning is required. Figure 9 shows the main user interface to the System Design Tools for Capacity Max. The SDT for Capacity Max covers three main areas as follows:

- Estimating the number of repeaters (trunked and data revert) needed at each site in the system
- Estimating the site link bandwidth needed for each site (RF or non-RF) in the system
- Determining the number of MNIS VRC Gateways needed in the system and estimating the number of Talkpath licenses needed for each MNIS VRC Gateway

Figure 9: System Design Tool User Interface for Capacity Max



Capacity Max System Server (CMSS)

A Capacity Max system requires at least one CMSS. A CMSS comes pre-installed with the Trunking Controller, the MNIS VRC Gateway, and the System Advisor server. All components must be licensed individually to function as described below.

Additional CMSS hardware may be purchased to support a redundancy of the Trunking Controller, the System Advisor server, or the MNIS VRC Gateway. Expansion CMSS hardware may be purchased to increase the number of VRC Gateways in the system. The maximum number of CMSSs allowed in a system is 10.

Note that for each RF site in the system, a Capacity Max Site License is required to enable it to attach to the system. Each CMSS (primary or backup) that hosts the Trunk Controller requires the appropriate number of Capacity Max Site Licenses.

Capacity Max Trunking Controller

A Capacity Max system requires at least one Trunk Controller, and can have a maximum of two.

The Trunking Controller software comes pre-installed on the Capacity Max System Server (CMSS) and a Trunk Controller license is mandatory for the system to function.

An additional Capacity Max Trunking Controller license for the backup CMSS may be purchased if redundancy is desired.

MNIS VRC Gateway

A MNIS VRC Gateway license must be purchased, to support wire-line voice and command applications such as voice consoles, voice recorders, or phone gateways. The MNIS VRC Gateway software comes pre-installed on the Capacity Max System Server (CMSS), but must have a license to function.

The system supports up to 5 primary MNIS VRC Gateways and 5 redundant MNIS VRC Gateways. Each MNIS VRC Gateway requires its own CMSS and its own license (whether primary or backup). The first pair (primary and alternate) of MNIS VRC Gateways can reside on the same CMSSs as the Trunking Controllers (primary and alternate). Additional MNIS VRC Gateways each require their own CMSS. Therefore the maximum number of MNIS VRC Gateways licenses allowed in a given system is 10.

Choosing the Number of MNIS VRC Gateways

The number of MNIS VRC Gateways is dependent on the voice and radio command applications being used. Voice and radio command applications can range from voice dispatch, to telephone interfaces, to logging recorders and applications that discreetly listen to ongoing group and private calls. Each voice and/or radio command application requires at least one VRC Gateway. Voice and radio command applications typically have a server and client relationship where their servers are associated with a single VRC Gateway. Some of the reasons for having multiple VRC Gateways are to allow more talkpaths than a VRC Gateway on a given CMSS can support, and to support a VRC Gateway per customer or application. Guidance is provided for selecting the appropriate number of VRC gateways. See chapter Number of VRC Gateways and Talkpaths Selection on page 123 for more details.

Sizing a VRC Gateway with the Required Number of Talkpaths

A VRC Gateway supports from 1 to 100 simultaneous external voice talkpaths. A talkpath is defined as the sourcing and receiving of one voice call. Therefore, the number of voice talkpaths a VRC Gateway requires is the number of calls that voice console can source and receive simultaneously. This is similar to the number of trunked repeaters a site requires. Voice applications such as logging recorders may have different needs. Command and control messaging like the radio commands does not require talkpaths. See chapter Number of VRC Gateways and Talkpaths Selection on page 123 for more details.

System Advisor

The System Advisor provides infrastructure equipment status, alarm and event reporting, and call activity monitoring. The system supports up to 2 System Advisors. The System Advisor server comes pre-installed on the CMSS, but must have a license to function.

The System Advisor client runs from a web browser on any computer (that meets the minimum hardware and software requirements) with a direct IP connection to the CMSS. See chapter Capacity Max Hardware Specifications on page 91 for more details.

Although the System Advisor is not required, it is highly recommended to include it as part of the Capacity Max System. For 3rd party applications, such as a manager-of-managers, to receive infrastructure equipment status, alarms, and event reporting, the System Advisor NorthBound Interface (NBI) license is needed.

Each CMSS running the System Advisor requires its own licenses (whether primary or backup).

Determining the Quantity and Location of RF and Non-RF Sites

A Capacity Max system supports up to 15 RF sites. The physical location of the RF sites must be determined based on the coverage needs of the end users. The process of selecting locations differs if

creating a new system, replacing an existing system, or if the physical location of the sites is dictated by the customer. Selection of the physical location of the non-RF sites (Trunk Controller, console, data applications, and others) is important as well, and can often be driven by user access and the user's operational needs. The IP network configuration is impacted by the location of the non-RF equipment in relation to the Trunk Controller and the RF sites.

RF coverage of a Capacity Max RF site is the same as previous MOTOTRBO architectures, which simplifies planning upgrades from Other MOTOTRBO systems to Capacity Max.

In general, however, there are many factors that affect RF performance prediction and the more factors that can be considered, the more accurate the prediction of coverage. Perhaps the most influential factor is the selection of the RF propagation model and/or RF prediction software tools.

In order for an RF site to connect to the Capacity Max system, a Capacity Max Site License is required. One Capacity Max Site License is included with the purchase of each Capacity Max Trunk Controller license, therefore requiring one less Site License than the number of actual RF sites. Capacity Max Site Licenses are required for CMSSs that host the primary Trunk Controller, and the backup Trunk Controller, if used. Therefore a maximum of 15 Site licenses (14 purchased) is allowed for systems with a single Trunk Controller, and a maximum of 30 Site licenses (28 purchased) is allowed for systems with a backup Trunk Controller.

Predicting the Number of Users and their Usage

In order to select the number of radio and repeaters appropriately, the first step is to determine the number of users and attempt to predict their voice and data usage. The number of group, individual and data calls per hour per user needs to be estimated, as well as the average call duration for group and individual calls. The distribution of users across the RF sites is also important. Typical usage profiles are identified and guidance is provided to determine if a customer is considered typical. See chapter Number of Users and Usage Prediction on page 99 for more details.

Capacity Max Subscribers

There are a wide range of different portable and mobile subscribers available, including low profile, display and non-display models.

Capacity Max can be configured with up to 90,000 radios and 10,000 talkgroups. The number of supported active radios is dependent on their usage profile. Generally, Capacity Max supports 45,000 active low usage users.

Each subscriber in the system must have a Capacity Max subscriber license. Capacity Max supports two subscriber license types as follows:

- An Advantage license (enables Advantage Mode)
- A Full license (enables Advantage, Open System, and Open Radio Modes)

NOTICE: All licenses are not available in all regions and availability must be determined from local ordering guides.

Subscriber Features

The following features are licensed per the subscriber, which vary by region and radio model; some licenses are offered as standard on certain models. They can be utilized in Capacity Max and other MOTOTRBO architectures.

- Transmit Interrupt (Voice Interrupt)
- Enhanced Privacy
- AES Privacy
- GPS Capable
- Enhanced GPS Capable

- Man-Down (CSA/ATEX) / Integrated Man-Down
- Data Services via Bluetooth
- Bluetooth Permanent Discovery Mode for Indoor Location
- Enhanced Option Board
- Text to Speech
- 280 Character Text Messaging
- SINC+
- WiFi

Capacity Max Trunking Repeaters

A Capacity Max system requires at least one trunking repeater per site, and currently supports up to 15 trunking repeaters per site. That is 30 logical channels, 29 trunked channels and 1 control channel. Each repeater must have a Capacity Max repeater license. Capacity Max supports two subscriber license types as follows:

- An Advantage license (enables Advantage Mode)
- A Full license (enables Advantage, Open System, and Open Radio Modes)

NOTICE: All licenses are not available in all regions and availability must be determined from local ordering guides.

Choosing the Number of Trunked Repeaters

The number of trunked repeaters at each site can be calculated based on the usage, the desired grade of service, and estimated inter-site communication. Charts and calculators are available to help. See chapter Number of Users and Usage Prediction on page 99 and Number of Trunking Repeaters Selection in Capacity Max on page 109 for more details.

Hardware Redundant Trunked Repeaters

Capacity Max already supports software redundancy in its design. For example if a control channel repeater fails, the next control channel capable repeater at the site takes over. Loss of the traffic channels means a lower grade of service, but the site still operates. A trunking repeater can optionally have hardware redundancy as well. This is most useful for control channel capable repeaters and especially useful if there is only one control channel capable repeater at a site. The redundant repeater's GPIO lines are wired to the primary repeaters GPIO lines and their RF input and outputs require an RF switch if sharing the same transmit and receive antenna system. See the chapter on *Repeater Hardware Redundancy in Capacity Max, in the Capacity Max System Installation and Configuration manual* for more details.

Capacity Max Data Revert Repeaters

A Capacity Max system supports up to 6 Enhanced GPS (Scheduled) Data Revert repeaters. Data Revert repeaters may be required, if the inbound data usage is too large and it cannot be supported on the trunking repeaters. There are two types of Payloads, which are IP Data and High Efficiency Data (CSBK). Guidance is provided to help select the appropriate configuration. See Capacity Max Data Revert Channel on page 35 for a description.

Each Data Revert repeater must have a Capacity Max repeater license. Capacity Max supports two license types as follows:

- An Advantage license (enables Advantage Mode)
- A Full license (enables Advantage and Open System Modes)

Choosing the Number of Data Revert Repeaters

The number of Data Revert repeaters at each site can be calculated based on the number of users, their GPS reporting rate, and the configuration of the Data Revert repeaters. Charts and calculators are available to help. See chapterNumber of Data Revert Repeaters Selection on page 117 for more details.

Hardware Redundant Data Revert Repeaters

Data revert repeaters can optionally have hardware redundancy. The redundant repeater's GPIO lines are wired to the primary repeaters GPIO lines, and their RF input and outputs require an RF switch if sharing the same transmit and receive antenna system. See the chapter on *Repeater Hardware Redundancy in Capacity Max, in the Capacity Max System Installation and Configuration manual* for more details.

Acquiring Frequencies from your Frequency Coordinator

The frequency licensing process varies from region to region. Before the license process begins, detailed information about the proposed radio system is usually required to be provided to the frequency coordinator. The appropriate emissions designators and guidance on other information is available to help. See chapter Acquisition of New Frequencies (Region Specific) on page 147 for more details.

Selecting the Appropriate Network Equipment

Typically, one network router and one network switch is required for each site. A multiple switch configuration per site is also available to remove the single point of trunking failure at a site. There are recommended network routers and switches for Capacity Max, for which configuration and troubleshooting support is provided. Functional requirements for selecting alternate routers and/or switches are provided. See chapter Network Components for Capacity Max IP Connectivity on page 129 for more details.

Determining and Acquiring the IP Bandwidth required for each Site

The amount of uplink and downlink IP bandwidth required at a site is determined by the number of simultaneous voice and data streams exiting and entering a site, and whether or not a CMSS (with VRC Gateway and/or System Advisor), Data Gateway, and/or Radio Management is present at the site. Charts and calculators are available to help. See chapter IP Bandwidth Per Site Requirement for Capacity Max on page 133 for more details.

Radio Management

A Capacity Max system requires Radio Management to configure the system. Radio Management can be installed on any computer, that meets the minimum hardware and software requirements, with a direct IP connection to the system. Radio Management consists of a four major components that can be installed on the same or different computers, as follows:

- Radio Management Client : Edits and Manages Configuration Data
- Radio Management Server : Storage of Configurations
- Radio Management Device Programmer : Programs All Managed Devices
- Radio Management Job Processor: Processes Scheduled Jobs

It is recommended that one computer be initially purchased to support all four components. This simplifies configuration and allows the configurations (the RM Server) to be stored with the system. Additional computers can be added to support remote RM clients and remote RM device programmers as the need arises. See chapter Capacity Max Hardware Specifications on page 91 for more details.

An MNIS Data Gateway is required to communicate to the radios over the air. See chapter Capacity Max Radio Management on page 69 and the chapter on *Radio Management Configuration in Capacity Max, in the Capacity Max System Installation and Configuration manual* for more details.

Battery Management

A Capacity Max system can optionally support a Battery Management application to manage the health of the radio's batteries in the system. Battery Management can be installed on any computer, that meets the minimum hardware and software requirements, with a direct IP connection to the system. Battery Management consists of a three major components that can be installed on the same or different computers, as follows:

- Battery Management Client : Main User Interface
- Battery Management Server : Storage of Configurations
- Battery Management Proxy : Communication to Radio System

It is recommended that one computer be initially purchased to support all three components. This simplifies configuration and allows the battery data to be stored with the system. Additional computers can be added to support remote clients as the need arises. An MNIS Data Gateway is required to communicate to the radios over the air.

Choosing the Number of MNIS Data Gateways

A Capacity Max system supports up to 5 MNIS Data Gateways. The number of needed Data Gateways is dependent on the data applications being purchased. A data application requires at least one Data Gateway. Data applications typically have a server and client relationship where their servers are associated with a single Data Gateway. Most data applications can share a Data Gateway, and the Data Gateway can reside on the same computer as the data application server, or on its own dedicated computer. See chapter Application Deployment Options with MNIS Data Gateways on page 119 for more details.

NOTICE: A Data Network Application Interface (NAI) license in each repeater is NOT required in Capacity Max.

Each Data Gateway requires its own license and a license for each Data Gateway is required for each CMSS that hosts a Trunk Controller, whether it is the primary or the backup Trunk Controller.

NOTICE: Redundant Data Gateways are NOT supported in Capacity Max. However since their access to the system is controlled via the CMSS running the Trunk Controller, licenses are required for each both the primary and backup CMSS, and therefore the maximum number of MNIS Data Gateways licenses allowed in a given system is 10.

Selecting the Appropriate Voice Console Applications

Several voice console application types from various manufacturers are supported in Capacity Max. These range from voice dispatch, to telephone interfaces, to logging recorders. The appropriate voice application that supports the customer's desired features must be identified. Marketing brochures are available to help with selection.

Selecting the Appropriate Data Applications

Numerous data application types from various manufacturers are supported in Capacity Max. These range from text message applications to location applications. The appropriate data application that supports the customer's desired features must be identified. Marketing brochures and catalogs are provided to help with selection.

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Chapter 2

Capacity Max Hardware Specifications

Relevant hardware specifications such as dimensions, power consumptions, operating temperature, are provided for each piece of equipment in the system. Hardware specifications of software on non-Motorola Solutions provided hardware.

Determination of how and where the equipment fits into the sites of the customer is important in Capacity Max system installation. The relevant hardware specifications such as dimensions, power consumptions, operating temperature, are provided for the following fixed end equipment:

- Capacity Max System Server (CMSS)
- Repeaters
- IP network equipment

Consider the Radio Frequency (RF) receiving and combining equipment and antenna space on the tower.

NOTICE: Information for the RF receiving and combining equipment is not provided here.

Some of the system software can be installed on personal computer are not provided by Motorola Solutions. The computer specifications for the following software are provided:

- Radio Management (Server, Client, Device Programmer, Tuner)
- Battery Management (Server, Client, Proxy)
- MNIS Data Gateway
- System Advisor Client
- ESU Client

Capacity Max System Server (CMSS) Hardware Specifications

The following is a summary of the CMSS hardware specifications.

Table 9: Summary for CMSS Hardware Specifications

Capacity Max System Server (CMSS)	
Height	8.73 cm (3.44 in)
Width	44.54 cm (17.54 in)
Depth	73.02 cm (28.75 in)
Weight	23.6 kg (51.5 lb)
Operating Temperature	10°C to 35°C (50°F to 95°F) at sea level with an altitude derating of 1.0°C per every 305 m (1.8°F per every 1000 ft) above sea level to a maximum of 3050 m (10,000 ft), no direct sustained sunlight. Maximum rate of change is 20°C/hr (36°F/hr). The upper limit and rate of change is limited by the type and number of options installed. System performance during standard oper-

Table continued…

	ating support may be reduced for an operation with a fan fault or above 30°C (86°F).
Non-operating Temperature	-30°C to 60°C (-22°F to 140°F) Maximum rate of change is 20°C/hr (36°F/hr).
Operating Relative Humidity	Minimum to be the higher (more moisture) of -12°C (10.4°F) dew point or 8% relative humidity. Maximum to be the lower (less moisture) of 24°C (75.2°F) dew point or 90% relative humidity.
Operating Altitude	3050 m (10,000 feet). This value is limited by the type and number of options installed. Maximum allowable altitude change rate is 457 m per minute (1500 feet per minute).
Non-operating Altitude	9144 m (30,000 feet). Maximum allowable altitude change rate it 457 m per minute (1500 feet per minute).
Operating Input Voltage Range	100–240 VAC
AC Power	100–240 VAC, 50–60 Hz
Power Consumption	• 800 W @ 120 V • 800 W @ 240 V
Input Current Drain	• 9.4 A @ 100 VAC • 4.5 A @ 200 VAC

Repeater Hardware Specifications

The following is a summary of the various hardware specifications of repeaters.

Table 10: Hardware Specifications for MTR3000*

		MTR3000			
Height		5.25” (3 RU)			
Width		19”			
Depth		16.5”			
Weight		40 lb/ 19 kg			
Band		VHF	UHF		800/900
Frequency (MHz)		136–174	403–470	470–524	
Tx Power (W)		100	100	100	100
Power Consumption	AC (W)	410	340	380	390
	DC (W)	350	300	320	340
Operating Temperature (°C)		-30/ +60			

Table 11: Hardware Specifications for XPR8400*

	XPR8400
Height	5.22” (3 RU)
Width	19”

Table continued…

Depth		11.7”				
Weight		31 lb/ 14 kg				
Band		VHF		UHF		
Frequency (MHz)		136–174		403–470		450–512
Tx Power (W)		25	45	25	40	40
Power Consumption	AC (W)	300	400	300	400	400
	DC (W)	100	160	100	160	160
Operating Temperature (°C)		-30/ +60				

Table 12: Hardware Specifications for XPR8380*

		XPR8380	
Height		5.22” (3 RU)	
Width		19”	
Depth		11.7”	
Weight		31 lb/ 14 kg	
Band		800/900	
Frequency (MHz)		806–870	896–941
Tx Power (W)		35	30
Power Consumption	AC (W)	400	400
	DC (W)	130	130
Operating Temperature (°C)		-30/ +60	

Table 13: Hardware Specifications for SLR5700*

		SLR5700	
Height		1.75” (1 RU)	
Width		19”	
Depth		14.6”	
Weight		19 lb/ 8.6 kg	
Band		VHF	UHF
Frequency (MHz)		136–174	400–470
Tx Power (W)		50	50
Power Consumption	AC (W)	180	180
	DC (W)	130	130
Operating Temperature (°C)		-30/ +60	

NOTICE: * See the following respective Motorola sites to get the full hardware specifications for each repeater per each region:

- NAG/LACR: http://businessonline.motorolasolutions.com
- EA: https://emeaonline.motorolasolutions.com

- APME: https://asiaonline.motorolasolutions.com

Hardware Specifications for Recommended IP Network Equipment

The following is a summary of the hardware specifications for the recommended IP Network Equipment.

NOTICE: Refer to manufacturer for additional specifications for the following recommendations.

Table 14: Hardware Specifications for HP MSR2003 AC Router

The recommended router for IP Network Routers.

HP MSR2003 AC Router	
Height	1.74” (1 RU)
Width	14.17”
Depth	11.81”
Weight	7.61 lb/ 3.45 kg
Operating Temperature	32°F to 113°F/ 0°C to 45°C
Maximum Power Rating (Watts)	54 W
AC Input Voltage	100 VAC to 240 VAC
AC Input Frequency	50 Hz to 60 Hz

NOTICE: Maximum power rating is the worst-case theoretical maximum numbers provided for planning the infrastructure with 100% traffic, all ports plugged in, and all modules populated.

Table 15: Hardware Specifications for Cisco 2911 Router

The recommended router for IP Network Routers.

Cisco 2911 Router	
Height	3.5” (2 RU)
Width	17.25”
Depth	12”
Weight	18 lb
Operating Temperature	@ 5,906 ft (1800 m) Altitude 32°F to 104°F/ 0°C to 40°C
Typical Power (No Modules) (Watts)	50 W
Maximum Power with AC Power Supply (Watts)	210 W
AC Input Voltage	100 VAC to 240 VAC (Auto Ranging)
AC Input Frequency	47 Hz to 63 Hz
DC Input Voltage	24 VDC to 60 VDC (Auto Ranging Positive or Negative)

Table continued…

DC Input Current	(Max) 8 A (24 V) 3.5 A (60 V)

Table 16: Hardware Specifications for HP Procurve 2530-24 Switch

The recommended router for IP Network Switches.

HP Procurve 2530-24 Switch	
Height	1.75” (1 RU)
Width	17.4”
Depth	9.7”
Weight	5.7 lb/ 2.59 kg
Operating Temperature	32°F to 113°F/ 0°C to 45°C
Maximum Power Rating (Watts)	14.7 W
AC Input Voltage	100 VAC to 127 VAC/ 200 VAC to 240 VAC
AC Input Frequency	50 Hz to 60 Hz

NOTICE: Maximum power rating is the worst-case theoretical maximum numbers provided for planning the infrastructure with fully loaded PoE (if equipped), 100% traffic, all ports plugged in, and all modules populated.

Table 17: Hardware Specifications for Cisco 3650 Switch

The recommended router for IP Network Switches.

Cisco 3650 Switch	
Height	1.73” (1 RU)
Width	17.5”
Depth	17.625”
Weight	24T - 15.15 lb (6.87 kg)24P - 16 lb (7.26 kg)
Operating Temperature	AC: -5°C to +45°C, up to 5000 ft (1500 m)DC: -5°C to +45°C, up to 6000 ft (1800 m)
Power Consumption (Watts) - (No more than) - Weighted Average	20T - 55.2124P - 64.18
AC Input Voltage	115 VAC to 240 VAC
AC Input Frequency	50 Hz to 60 Hz
DC Input Voltage	-36 VDC to -72 VDC
DC Input Current	21 A to 10.5 A

NOTICE: Weight includes the chassis assembly as it is shipped: three fans, two Stackwise adapters, and one power supply blank. The weight also includes the default power supply that is shipped with the unit.

Computer Specifications of Application

Some of the system software must be installed on personal computers. The computer minimum specifications for the following software applications are provided:

- Radio Management (Server, Client, Device Programmer, Tuner)

- Battery Management (Server, Client, Proxy)
- MNIS Data Gateway
- System Advisor Client
- ESU Client

All the listed software can coexist on the same computer. If the computer meets the sum of their specifications, all the software can run simultaneously.

Radio Management Computer Specifications

The Radio Management (RM) software can be installed on any personal computer that meets the following computer specifications.

Table 18: Recommendations for Radio Management Computer Specifications

Parameters	Recommendations
Operating System Requirements	**Standalone Radio Management Client (CPS), Standalone Radio Management Device Programmer, or Tuner** • Windows 8, Windows 8.1, 32-bit and 64-bit • Windows 7 Home Premium or Professional (SP1 or higher) 32-bit and 64-bit
	Radio Management Client (CPS) with Radio Management Server and Radio Management Device Programmer • Windows 8, Windows 8.1, 32-bit and 64-bit • Windows 7 Home Premium or Professional (SP1 or higher) 32-bit and 64-bit • Windows Server 2008 R2 SP1 32-bit and 64-bit
Recommended Hardware Requirements for Small Fleets (<1000 Radios)	• Processor: 2 GHz dual core or higher Pentium grade processor • Memory: 4 GB RAM • Aero capable graphics card with 128 MB graphics memory • 50 GB free hard disk space on a 5400 RPM hard disk drive • USB Port for radio communication • DVD-ROM for software installation **NOTICE:** Managing more radios (>1000) will require more processing power in the server. See the *Radio Management Deployment Guide* for more details on selecting the appropriate hardware for the appropriate deployment and fleet size.

Battery Management Computer Specifications

The Battery Management software can be installed on any personal computer that meets the following computer specifications.

Table 19: Recommendations for Battery Management Computer Specifications

Parameters	Recommendations

Table continued…

Operating System Requirements	• Windows 7 x86 and x64 • Windows 8 x86 and x64 • Windows Server 2003 x86 and x64 • Windows Server 2008 x86 and x64 • Windows Server 2008 R2 x64
Hardware Minimum Requirements	The IMPRES^{TM} Battery Fleet Management application is installed on a client/proxy computer or a server computer. The installation package is the same for client and server computers, but the hardware installation requirements are different for each.
Server Hardware Minimum Requirements	• DVD drive **NOTICE:** If software downloaded from website, DVD drive is not required. • 1 GB of hard disk space • 2 GB RAM
Client/Proxy Hardware Minimum Requirements	• 1 Universal Serial Bus (USB) Port • DVD drive **NOTICE:** If software downloaded from website, DVD drive is not required. • 200 MB of hard disk space • 1 GB RAM

MNIS Data Gateway Computer Specifications

The Data Gateway (MNIS) software can be installed on any personal computer that meets the following computer specifications.

Table 20: Recommendations for MNIS Data Gateway Computer Specifications

Parameters	Recommendations
Operating System Requirements	• Windows 8, Windows 8.1, 32-bit and 64-bit • Windows 7 Home Premium or Professional (SP1 or higher) 32-bit and 64-bit • Windows Server 2008 R2 SP1 32-bit and 64-bit
Hardware Minimum Requirements	• 5 GB of hard disk space • 1 GB RAM **NOTICE:** Running multiple instances of MNIS on the same hardware is not supported.

System Advisor Client Computer Specifications

The System Advisor Client software can be installed through a web browser on any personal computer that meets the following computer specifications.

Table 21: Recommendations for System Advisor Client Computer Specifications

Parameters	Recommendations
Operating System Requirements	• Windows 8, Windows 8.1, 32–bit and 64–bit • Windows 7 Home Premium or Professional (SP1 or higher) 32–bit and 64–bit • Windows Server 2008 R2 SP1 32–bit and 64–bit
Hardware Minimum Requirements	• 2 GB of hard disk space • 2 GB RAM
Software Requirements	• Recent versions of IE with at least IE v11, FireFox with at least FireFox v20+, or Chrome with at least Chrome v43+ • Recent versions of Oracle Java 8 32–bit (v1.8.0_66 or greater)

ESU Client Computer Specifications

The ESU Client software is accessed through a web browser on any personal computer that meets the following computer specifications.

Table 22: Recommendations for ESU Client Computer Specifications

Parameters	Recommendations
Software Requirements	A web browser that supports HTML5. • Internet Explorer v10 • FireFox v40 • Chrome v43

Chapter 3

Number of Users and Usage Prediction

This chapter describes the initial steps in determining the number of users, and attempt to predict their voice and data usage, to size the system appropriately. The number of group, individual and data calls per hour per user needs to be estimated, as well as the average call duration for group and individual calls. The distribution of users throughout the RF sites is equally important. Typical usage profiles are identified and guidance is provided to determine if a customer is considered typical.

Overview

Sizing the system correctly is an important part of planning for a Capacity Max system. The following are the quantities, that often define the size of a system:

- Radios
- RF sites
- Trunked repeaters
- Data revert repeaters
- Voice gateway talk paths

The first step to determine these quantities is to predict the system usage, and the usage is made up of the following:

- The number of simultaneously active radio users in the system and at each site
- The radio user’s call rate and call duration
- The average number of sites participating in a call
- The voice console call rate and call duration
- The number of outbound data application transmissions per hour
- The inbound periodic location transmissions per user

Sections below details the prediction of system usage. Once the values have been predicted, they can be utilized in Number of Trunking Repeaters Selection in Capacity Max on page 109, Number of Data Revert Repeaters Selection on page 117 and Number of VRC Gateways and Talkpaths Selection on page 123. The information determined in these sections can be used as input to the Capacity Max System Capacity Estimator that is part of MOTOTRBO System Design Tools.

Active Radio Users in the System Simultaneously

The number of users a system must support is the primary question, that drives the purchase of the system’s radios. This number may be easy to acquire, if replacing a system, but if installing a new system a series of customer interviews with pointed questions may be important.

The total number of radios purchased for a system does not mean all will be active at any given time. If the organization operates in shifts, a percentage of the total number of radios may be active at any particular shift. Even if a user operates in shifts, they may hand-off a single set of radios between shifts, therefore the total number of radios may actually represent the number of simultaneously active users.

It is a good idea to utilize the peak number of simultaneously active users. If the previous communication system logged radio registrations, it may be an advantage to browse the logs, to determine the peak number of registered users per day, per week, and during special events.

Future expansion should be also another consideration. If the customer knows that they will be expanding their business in the near future, it might be wise to increase the estimated number of simultaneously active users.

Predicting the Number of Simultaneously Active Radio Users at Each Site

Active users are spread over numerous sites, in a multi-site system. A site's resources such as the trunked repeaters, data revert repeaters, and others must be planned for each site; therefore it is important to understand the distribution per site.

If users generally stay within the coverage of a single site, then it is straight forward to determine the number of simultaneously active users for each site. The **average number of simultaneously active users at a site**, can be simply found by dividing the total number of active users on the system by the number of sites. This creates a balanced system, which is easiest since each site has identical requirements.

NOTICE: If specific information is available about the user density of a particular site, for example covering a town versus the countryside, then it may be necessary to load some sites with more users than others.

If only a few users are mobile, that is moving between sites, they can be accounted for at each site they may visit; therefore the maximum number of simultaneously active users at a site would be the summation of the active stationary users and the active mobile users. It is unlikely that all mobile users would end up at one site at the same time and impossible that they all show up at every site at the same time, but the impact of adding resources at every site to accommodate the few may be unimportant.

If most of the users of a system are mobile, prediction can become complicated.

The safest strategy is to presume that all the users in the system may end up at a single site at some point, but sizing every site to support every radio in the system may be extremely wasteful since that scenario is not very likely.

It is reasonable to think that in a system with highly mobile users that as many users leave a site as there are users entering a site. Therefore the average number of simultaneously active users at a site remains uniform across all sites. There may be some scenarios where this assumption is not true. For example, there may be a centralized site that all users travel through at the beginning of a shift, or there may be scenarios where a percentage of users from adjacent sites often enter a site without the same number of users exiting a site. The extra number of users that roam to the site should be accounted for in the **maximum number of simultaneously active users at a site**.

If the previous communication system logged radio registrations per site, it may be advantages to browse the logs to determine the peak number of registered users per site, per day, per week, and during special events. This will take the guess work out of determining the average and maximum number of simultaneous active users at a site.

Radio User's Call Rate and Call Duration Prediction

After the number of simultaneously active users per site is determined, the rate at which they transmit must be predicted. The call rate is quantified by a number of calls per user per hour. There are three call types to consider, which are the group calls, individual calls, and data messaging. An example of data messaging is text messaging, although other types of asynchronous data can be handled similarly. Periodic location data is considered in another section.

There are different call types supported in the system like the emergency, site call, radio check, and other. It is assumed that these call types only occur occasionally and do not affect loading. If a user

utilizes an abnormally large amount of these call types, or if they utilize a specialized data application, their impact on loading may wish to be considered.

There are three strategies to predict the user's call rate, which are to interview the customer, review log files, or use typical usage profiles.

Interview the Customer

NOTICE: Discuss with the customer about their usage. The amount of information acquired from interviews varies.

Customers may not know the actual average call rate or call duration of their users, the average number of text messages, group calls, or individual calls their users perform per hour; therefore extra cautiousness is needed, when numbers are provided.

Some customers may only be able to identify the call type they use the most and little. For example, some customers infrequently utilize individual calls, but some primarily utilize them. Some parts of their organization primarily utilize text messaging to communicate, while others never use text messaging. Some users may be known for their long detailed conversations on the radio system, while others communicate using 10 codes. These approximations will help shape the usage profiles. It is recommended to follow up, to determining the number of users utilizing these usage profiles and which sites are they located at, approximately.

Review Log Files

Customers who review their call logs regularly, could provide a confident data related to their usages. If the previous communication system call logs are available, acquire them and verify the peak call rate for the peak hour of the peak day of the week, and during special events.

Cautiousness is necessary, when reviewing the logged data, as they must be read and interpreted correctly. Logged data can often be misleading.

NOTICE: Be aware if transmissions, or calls consisting of numerous transmissions are logged, as this can often distort the call rates and call durations.

Typical Usage Profiles

If historic system call logs are not available from the customer, typical usage profiles can be utilized. There are two levels for each traffic; a typical low usage or light traffic user, and a typical high usage or heavy traffic user. A medium user can easily be extrapolated. It is easiest if all users within a system can be generalized to one of the existing profiles. The profiles must be adjusted, if no profile aligns with the information acquired from the customer interviews.

Profile Name	Talkgroup Call Rate (call per user per hour)	Average Talkgroup Call Duration (seconds)	Individual Call Rate (call per user per hour)	Average Individual Call Duration (seconds)	Data Message Call Rate (call per user per hour)	Data Message Call Duration (seconds)	Total Call Rate (call per user per hour)	Weighted Average Call Duration (seconds)
High Voice User	2.7	10	0.3	20			3	11
Low Voice User	0.9	10	0.1	20			1	11
High Text User					2.5	1.5	2.5	1.5
Low Text User					0.5	1.5	0.5	1.5
High Voice and Text User	2.7	10	0.3	20	2.5	1.5	5.5	6.68
Low Voice and Text User	0.9	10	0.1	20	0.5	1.5	1.5	7.83

The above profiles represent a quasi-transmission trunking model with a short voice call hangtime. On average, group calls consists of 2 transmissions, and individual calls consists of 4 transmissions. Setting call hangtime to zero (transmission trunking) will increase the call rate (multiplied by the number of transmissions within a call), and lower the call duration (minus the call duration times the number of transmissions with a call). Setting the call hangtime to a very large number (message trunking), will increase the overall call duration.

When combining call rates and durations with other call rates and durations within a profile, the call rates can be simply added up, but the call durations cannot simply be averaged, they must be

weighted by the call rate. For example, the profile's weighted average call duration is calculated as follows:

$$\text{Profile Weighted Average Call Duration} = \frac{\left(\text{Talkgroup Call Rate} \times \text{Talkgroup Call Duration}\right) + \left(\text{Individual Call Rate} \times \text{Individual Call Duration}\right) + \left(\text{Data Call Rate} \times \text{Data Call Duration}\right)}{\text{Talkgroup Call Rate} + \text{Individual Call Rate} + \text{Data Call Rate}}$$

Therefore, for the High Voice and Text User profile in the table above, the profile's weighted average call duration is as follows:

((2.7 x 10) + (0.3 x 20) + (2.5 x 1.5)) / (2.7+0.3+2.5) = 6.68 seconds

It is easiest if all users within a system can be generalized to one profile. For example if all 1200 users at a site can all be considered to be 'high voice and text' users.

Through interviews, the customer may say some parts of their organization only utilize text messaging to communicate, while others primarily utilize voice calls. They also may say some users infrequently utilize individual calls, while some primarily utilize individual calls. General statements like this may require user weighting between a few different altered profiles. Below is an example of how this might be distributed. The customer would need to provide additional information on the quantities of users for each profile.

# of Users	Profile Name	Talkgroup Call Rate (call per user per hour)	Average Talkgroup Call Duration (seconds)	Individual Call Rate (call per user per hour)	Average Individual Call Duration (seconds)	Data Message Call Rate (call per user per hour)	Data Message Call Duration (seconds)	Total Call Rate (call per user per hour)	Weighted Average Call Duration (seconds)
300	High Text User					2.5	1.5	750	1.5
600	High Group, Low Individual, Low Text User	2.7	10	0.3	20	0.5	1.5	2100	9.64
300	Low Group, High Individual User	0.3	10	2.7	20			900	19
1200	Total Users						Total	3750	10.26

When combining profiles the call rates are multiplied by the number of users utilizing that call rate and then simply added up, but the call durations of the profiles cannot simply be averaged, they must be weighted by the total call rate of each set of users. For example, the total weighted average call duration is calculated as follows:

$$\text{Total Weighted Average Call Duration} = \frac{\left(\text{Profile 1 Call Rate} \times \text{Profile 2 Call Duration}\right) + \left(\text{Profile 2 Call Rate} \times \text{Profile 2 Call Duration}\right) + \left(\text{Profile n Call Rate} \times \text{Profile n Call Duration}\right)}{\text{Profile 1 Call Rate} + \text{Profile 2 Call Rate} + \text{Profile n Call Rate}}$$

Therefore, for all the profiles in the table above, the total weighted average call duration is as follows:

((750 x 1.5) + (2100 x 9.64) + (900 x 19)) / (750+2100+900) = 10.26 seconds

Average Number of Sites in a Call Prediction

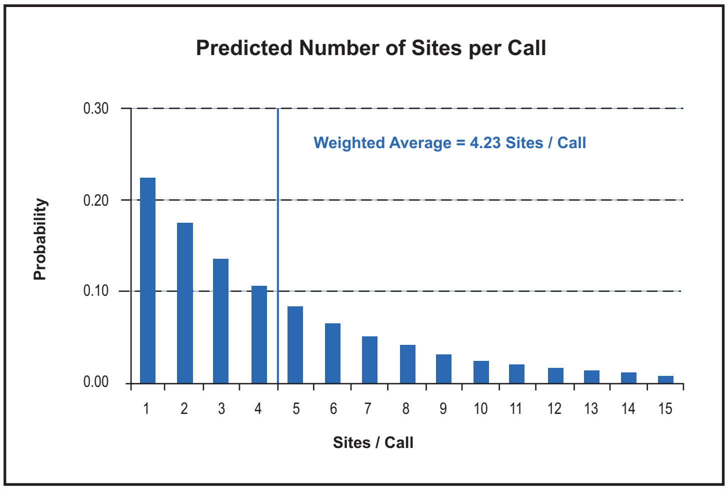
The average number of sites participating in a call (sites per PTT) is an important factor in a multi-site Capacity Max system. It affects how many calls initiated from a site are routed to how many other sites, which affects the number of trunked resources at those sites and the IP link bandwidth.

The average number of sites participating in a call, minus one, is multiplied by the average number of users at each site multiplied by their call rate to determine the incoming call rate and the outgoing call rate.

Dynamic Talkgroup Affiliation

The average number of sites participating in a call can be different based on customer usage. As a user moves to a site and affiliates to a talkgroup, that site is included in the talkgroup call and the number of sites participating in a call increases. The following chart shows the typical distribution of sites per PTT for systems with a large number of sites.

Site / Call	Probability
1	0.2238
2	0.1744
3	0.1360
4	0.1061
5	0.0829
6	0.0648
7	0.0507
8	0.0398
9	0.0313
10	0.0247
11	0.0195
12	0.0155
13	0.0124
14	0.0100
15	0.0081



If a system supports less than fifteen sites, then the percentage associated with the larger number of sites can be adjusted by distributing it across the remaining sites. This keeps the general trend as the number of sites lowers, and lowers the weighted average of the distribution. The following table summarizes the typical weighted average sites per call versus the number of sites in the system.

Table 23: Typical Weighted Average Sites per Call Versus Number of Sites

Number of Sites	Average Sites per Call
1	1.00
2	1.48
3	1.91
4	2.30
5	2.65
6	2.95
7	3.21
8	3.43
9	3.61
10	3.77
11	3.90
12	4.01
13	4.10
14	4.17
15	4.23

A customer’s unique usage will define the values, although this is considered typical. The average sites per call can be adjusted up if the customer makes an abnormally large number of wide area calls or if their users within their talkgroups are spread out over an abnormally large number of sites. It is

important to understand that the number of sites per call is a distribution as shown above, and fractional values for the weighted average are common.

The weighted average sites per call values above are an average over all sites. For example some sites with voice consoles, may have an abnormally high sites per PTT value than other sites, but this is normalized in the averaging. Sites with an abnormally high sites per PTT value may need to be handled separately when calculating the required outbound IP bandwidth, but for choosing the number of trunked repeaters, a system wide average is acceptable.

NOTICE: If the previous communication system call logs are available, acquire them and review the average number of sites participating in each call.

Static Talkgroup Affiliation

Capacity Max allows statically configured talkgroup to site affiliations. Statically configured talkgroup to site affiliation means that regardless if a user has dynamically affiliated a talkgroup to a site, the calls for a talkgroup will always be routed to that site. If a large number of statically configured talkgroup to site affiliations are utilized, this must be accounted for in the average sites per call value. For example if 80% of the talkgroups of a 15 site system have 7 sites statically configured, then the average is probably not 4.23, but rather somewhere between 4.23 and 7. Consider using the weighted average (0.8x7) + (0.2x4.23) /1, which is 6.4 average sites per PTT. The maximum number of statically configured sites per talkgroup is 15.

Voice Console Call Rate and Call Duration Prediction

The number of outbound voice console calls, which are calls placed from the wireline console, is another important factor in a Capacity Max system. It affects how many calls initiated from a console are routed to the RF sites, which affects the number of trunked resources and the IP link bandwidth. It also affects the number of voice gateways talkpaths necessary, which affects the number of voice gateways.

It is important to not double count console calls. If the consoles simply respond to inbound radio transmissions, then their load may have already been accounted for by the radio usage profiles; but if the consoles initiate a large portion of the system calls, then they should be accounted for separately since they do not affect the inbound control channel load.

It is recommended to interview the customer and review available log files, as predicting radio usage. The interviews may provide general usage descriptions where as the log files will provide specifics.

The outgoing voice calls a voice console initiates per hour, has to be determined. A high use operator may make one voice group call every 1 minute, whereas a low user operator may make a voice call every 10 minutes. The number of outbound voice console calls can be different based on customer usage. It is assumed that their call duration matches what was defined for the radios, but if that is not the case, the voice console call duration should be increased or decreased as necessary.

The number of consoles multiplied by their call rate multiplied by the number of average sites per call, provides the call rate the consoles place on the system. Then evenly dividing by the number of sites results in the call rate a site receives from the consoles.

Outbound Data Application Transmissions per Hour Prediction

The impact from the number of outbound data application transmissions may need to be considered. Outbound data application transmissions are routed to the RF sites, which affects the number of trunked resources and the IP link bandwidth. The impact of these data transmissions is usually small, but if an abnormally high rate of transmissions are occurring, it could impact the system performance.

If text messages are sent between the radios and a data application, rather than just radio to radio, the outbound call rate should be accounted for. The inbound call rate should have already been accounted for in previous sections within the radio user’s call rate and call duration. It is important to separate the

inbound and outbound call rate values since outbound data traffic does not impact the inbound control channel capacity, but impacts the number of repeaters required and the outbound control channel capacity.

The text message rate per hour per radio should be multiplied by the number of radios, to account for the outbound responses from the data application.

NOTICE: Other data application messaging is different. Similar outbound traffic should be included for any other data applications that send data to the radios.

Inbound Periodic Location Transmissions per User

The desired inbound periodic location transmission rate (outdoor or indoor) is configurable, and not directly based on the action of radio users, unlike the other usages. This allows the amount of location tracking load to be centrally managed by an administrator, by increasing or decreasing the requested update transmission rate. High update rates can add a high load on a system, and should be managed correctly.

- Firstly is to determine the number of users in the system, and ultimately at a site, which requires location tracking. It is common that only a percentage of the users need to be tracked.
- Secondly is to determine the normal update rate for all the users. It is not always necessary to track every user at the highest update rate at all the time, although it is supported. A five minute update rate is usually sufficient for many users.

The update rate of individuals can be increased to the maximum of 7.5 seconds when necessary, although a 30 second update rate is sufficient in most scenarios. A 7.5 second update rate is available in some configurations. If a 7.5 second update is required; the high efficiency option, which utilizes compression and data revert channels must be utilized. It is important to understand, the number of users that may have high update rate at one particular time, as it determines the required appropriate resources.

Location transmissions can be sent on the trunked channels, but the number of users and call rates are limited. Data revert channels are available to support a higher number of users and a higher call rate. A high efficiency option that utilizes compression is available to increase capacity, but not all GPS parameters are provided. A scheduled revert channel is also available that optimizes the inbound delivery of the location tracking which increases the call rate even higher.

Guidance is available to determine which configuration is necessary, once the customer’s desired inbound periodic location transmission rate has been determined.

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Chapter 4

Transmission, Message and Quasi Transmission Trunking

This chapter describes the differences between Transmission Trunking, Message Trunking and Quasi Transmission Trunking, the configurations, and how the selection can impact the number of trunked repeaters required at a site

Overview of Voice Call Trunking Type and Configuration

Capacity Max voice calls can be configured to support the following Trunking Types:

Transmission Trunking

Every voice transmission starts with a control channel request for a trunked channel. The voice call hangtime is set to 0 to enable Transmission Trunking.

Message Trunking

The first transmission of a voice call starts with a control channel request for a trunked channel, and all subsequent transmissions during the duration of the voice call are initiated on the trunked channel. The voice call hangtime is set large, where it can be multiples of 10 seconds, with Message Trunking.

Quasi Transmission Trunking

The first transmission of a voice call starts with a control channel request for a trunked channel, and all subsequent transmissions during the duration of the voice call are initiated on the trunked channel. The voice call hangtime is set small, like few seconds maximum, with Quasi Transmission Trunking.

Trunking Type Effects

Transmission trunking adds loading to inbound control channel, maximizes trunked channel efficiency (for example, Erlangs), and comes with a risk of call continuity disruption. This results in the fewest required trunked channels for a given load.

Message trunking minimizes loading on the inbound control channel, and minimizes risk to call continuity disruption at the expense of decreasing trunked channel efficiency. The trunked channel efficiency decreases, as the hangtime value is increased. This results in the most required trunked channels for a given load.

NOTICE: A Capacity Max allows a group call initiator or either member of an individual call to end the call during hangtime, to improve the trunked channel efficiency.

Quasi transmission trunking minimizes loading on the control channel. It settles between Transmission and Message Trunking, in terms of call continuity disruption and trunked channel efficiency risk. The required trunked channels for a given load will reside between Trunked and Message trunking channels.

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Chapter 5

Number of Trunking Repeaters Selection in Capacity Max

This chapter describes how the number of trunked repeaters at each site can be calculated, based on the predicted usage. Adequate information, charts and calculator are provided to verify, that the loading does not exceed any of the system limitations.

Overview

There are three different strategies for choosing the appropriate number of trunking repeaters in a trunking system, where some strategies are more accurate than others. The strategies involved are a simple strategy, a better strategy, and the best strategy.

Strategy Types

The following are the strategies used, for choosing the number of trunking repeaters in a trunking system:

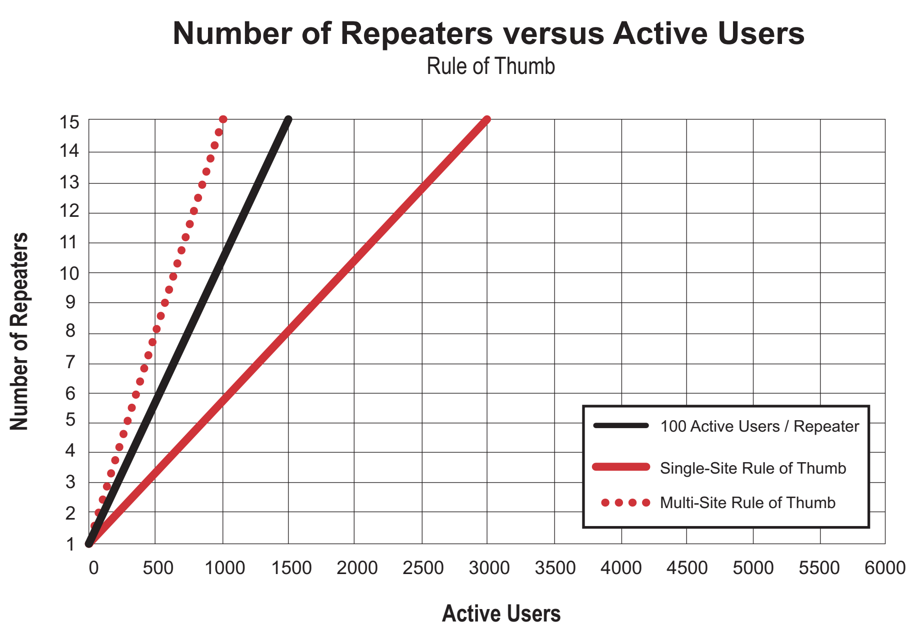
Simple Strategy

A simple strategy is to use a long time general rule of thumb to determine the number of trunking repeaters from the number of active users. The historical rule of thumb is the number of active users divided by one hundred equals the number of repeaters.

NOTICE: This is a gross approximation and may or may not yield desirable results. The result could be off by five repeaters, plus or minus.

Figure 10 shows two additional rule of thumbs; one for single site, and one for multi-site. A rule of thumb early in the design process may be sufficient, but it is recommended to invest more time sharpening the predictions prior to ordering the equipment.

Figure 10: Number of Repeaters versus Active Users in Simple Strategy

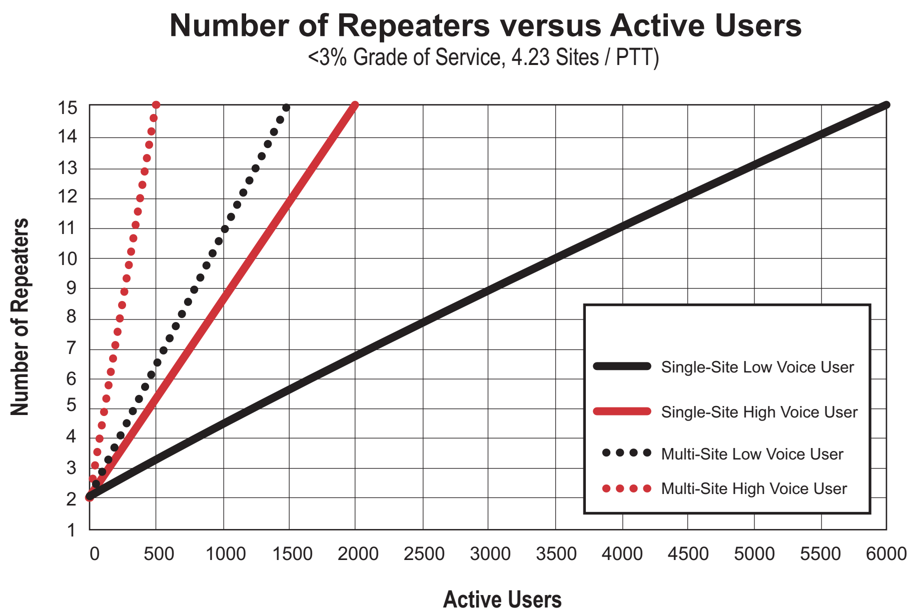


Better Strategy

A better strategy to calculate the number of trunking repeaters more accurately, is to predict the rate at which calls are requested and the average call duration. Different call rates and call durations are combined into typical user call profiles such as the high voice users, low voice users, and others, and they are multiplied with the number of active users.

This can yield the total call rate and the average call duration for a site. Accompanied by a fixed grade of service, and a fixed number of sites participating in a call (Sites per PTT), a more accurate number of trunking repeaters can be calculated. This level of accuracy is sufficient for voice only systems without voice consoles. Figure 11 shows how to determine the number of repeaters based on the number of active users for a single-site system with high or low voice users, or multi-site system with high or low voice users. Refer to Number of Users and Usage Prediction on page 99 for more information on the profile definitions.

Figure 11: Number of Repeaters versus Active Users in Better Strategy

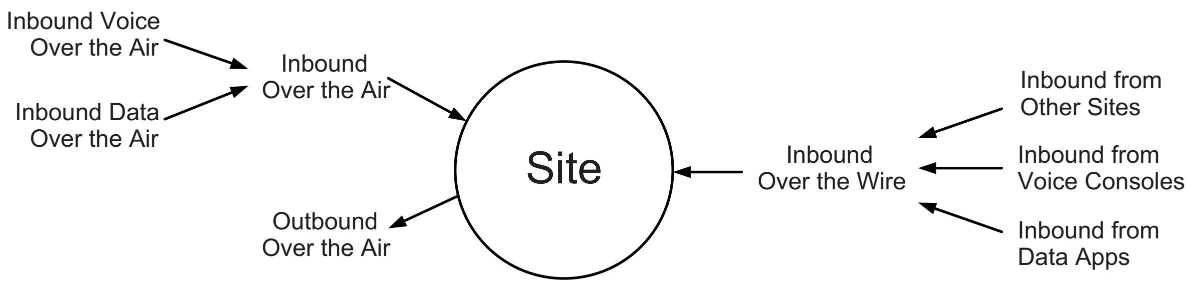


Best Strategy

The best strategy is to account for all call rates and call durations for all call types such as the group voice, individual voice, and data messages; entering the site from all inputs such as the inbound over the air, inbound from other sites, inbound from voice consoles, and inbound from data applications. The best strategy is to account for the uniqueness of a particular customer's radio users, by creating more accurate call profiles and combining them, rather than normalizing all radio users to one call profile. Additionally, an acceptable grade of service can be used to calculate an accurate number of trunking repeaters. This chapter and the chapter on Number of Users and Usage Prediction on page 99 explains how all these considerations are combined together to yield the total call rate and the average call duration.

Figure 12 summarizes the inputs and outputs of interest for a site.

Figure 12: The Inputs and Outputs of Interest for a Site



In addition to finding the number of repeaters required per site, it is important to understand a few system limitations: the maximum supported number of repeaters per site, the over the air call rate limit, the outbound announcement call rate limit (total call rate for the site), and the over the air registration limit. Staying under these limits can only be determined if all site inputs are considered.

Number of Users and their Usage Prediction

See the chapter on Number of Users and Usage Prediction on page 99, for proper guidance in determining the number of users and their usage. The following values should already been predicted:

- The number of simultaneously active radio users in the system and at each site
- The radio user’s call rate and call duration
- The average number of sites participating in a call
- The voice console call rate and call duration
- The number of outbound data application transmissions per hour
- The inbound periodic location transmissions per user.

These usage parameters are utilized to calculate the number of required trunked repeaters, and to determine if any system limitations have been exceeded.

NOTICE: The accuracy of the output is highly dependent on the accuracy of the predicted usage.

Configuration Tools (Use of Capacity Max System Capacity Estimator)

Configuration tools are available, that accept the number of users and their usage as inputs, and provide the number of trunking repeaters required. The tool is more precise as it can use the exact provided values, to calculate the number of trunking repeaters. The information determined in this section can be used as input to the Capacity Max System Capacity Estimator that is part of MOTOTRBO System Design Tools.

Number of Trunking Repeaters Calculation

The following describes the calculation of the Total Call Rate for the Site and the Average Weighted Call Duration for the Site, when a configuration tool is unavailable. Figure 4 in Number of Required Trunking Repeaters on page 114 illustrates these two values, together with a fixed grade of service, to determine the number of repeaters required.

- **Total Call Rate for the Site**

The total call rate for the site is the over the air call rate plus the over the wire call rate.

$$\text{Total Call Rate for the Site} = \text{Over the Air Call Rate} + \text{Over the Wire Call Rate}$$

Over the Air Call Rate

The over the air call rate is the over the air voice call rate, plus the over the air data call rate. If the voice and data call rates were already combined into one call rate, the combined call rate can simply be multiplied by the number of simultaneous active radio users at a site.

$$\text{Over the Air Call Rate} = \text{Over the Air Voice Call Rate} + \text{Over the Air Data Call Rate}$$

Over the Air Voice Call Rate

The over the air voice call rate is the number of active radio users at a site, multiplied by the radio user's voice call rate. This should include the call rate of group calls and individual calls. The over the air voice call rate will be required, when determining if the inbound registration limit is exceeded.

$$\text{Over the Air Voice Call Rate} = \text{\# of Active Users} \times \text{Radio User Voice Call Rate}$$

Over the Air Data Call Rate

The over the air data call rate is the number of active radio users at a site multiplied by the radio user's data call rate. This should include the call rate of text messaging, inbound location, or any other inbound data.

The location call rate should be included, only if radios are sending their location on the trunked channels. Location transmissions can be sent on the trunked channels, but call rate limitations will be quickly surpassed. Data revert channels are available to support a higher number of users and a higher call rate. Refer to Number of Data Revert Repeaters Selection on page 117.

$$\text{Over the Air Data Call Rate} = \text{\# of Active Users} \times \text{Radio User Data Call Rate}$$

Over the Wire Call Rate

The over the wire call rate is the other sites call rate, plus the voice console call rate, plus the data application call rate.

$$\text{Over the Wire Call Rate} = \text{Other Sites Call Rate} + \text{Voice Console Call Rate} + \text{Data Application Call Rate}$$

Other Sites Call Rate

The other sites call rate is the rate at which calls from other sites are routed to this site. The other sites call rate is the over the air call rate (from above) multiplied by the average number of sites participating in a call (Average Sites per Call) minus one. This assumes that the over the air call rate for this site is representative of other sites.

$$\text{Other Sites Call Rate} = \text{Over the Air Call Rate} \times \left(\text{Average Sites per Call} - 1 \right)$$

Voice Console Call Rate

The voice console call rate is the rate at which calls from the voice consoles are routed to this site. The voice console call rate is the number of voice consoles, multiplied the voice console call rate per voice console, multiplied by the average number of sites per call, and then divided by the number of sites in the system.

$$\text{Voice Console Call Rate} = \frac{\text{Number of Voice Consoles} \times \text{Voice Console Call Rate Per Voice Console} \times \text{Average Sites per Call}}{\text{Number of Sites}}$$

Data Application Call Rate

The data application call rate is the number of outbound data application transmissions per hour. It could be calculated as the number of outbound data messages sent to each radio multiplied by the average number of active users at the site.

$$\text{Data Application Call Rate} = \text{\# of Active Users} \times \text{Data Application Call Rate per User}$$

- **Average Weighted Call Duration for the Site**

When combining durations with other durations, the call durations cannot simply be averaged; they must be weighted by the rate at which they occur (that is, the call rate). This must occur for all call rates that have unique call durations.

– Over the Air Voice Call Rate and Call Duration

– Over the Air Data Call Rate and Call Duration

– Other Sites Call Rate and Call Duration

– Voice Console Call Rate and Call Duration

– Data Application Call Rate and Call Duration

The following equation can be utilized to find the average weighted call duration of these parameters.

$$\text{Average Weighted Call Duration} = \frac{\left(\text{Call Rate 1} \times \text{Call Duration 1}\right) + \left(\text{Call Rate 2} \times \text{Call Duration 2}\right) + \left(\text{Call Rate n} \times \text{Call Duration n}\right)}{\text{Call Rate 1} + \text{Call Rate 2} + \text{Call Rate n}}$$

NOTICE: The other sites call duration is actually the average weighted call duration of the over the air voice call rate and call duration and the over the air data call rate and call duration. Most spreadsheet applications have a SUMPRODUCT function to help with the average weighted call duration.

Grade of Service

The system grade of service is the percent of transmission requests (PTTs) that are immediately serviced. A system with a 100% grade of service will experience no queuing. The blocking rate, like the busy rate or queuing rate, is the percent of transmission requests (PTTs) that are queued because there are no resources available. The queued radio user receives a talk permit tone, when a resource is available. Therefore the blocking rate is, 1 - grade of service.

The blocking rate is important in calculating the number of repeaters at a site. The lower the blocking rate, more repeaters are required to service a particular call rate and average call duration. The number of repeaters at a site is typically calculated to achieve better than 3% blocking rate. Figure 4 is created and illustrated using a 3% blocking rate.

System Blocking Rate

The system blocking rate is slightly different than the site blocking rate. In a multi-site system, where multiple sites participate in a call, a resource must be available at each of the sites participating in the call. The system blocking rate is calculated as follows:

$$\text{System Blocking Rate} = 1 - \left(\left(1 - \text{Site 1 Blocking Rate} \right) \times \left(1 - \text{Site 2 Blocking Rate} \right) \times \left(1 - \text{Site n Blocking Rate} \right) \right)$$

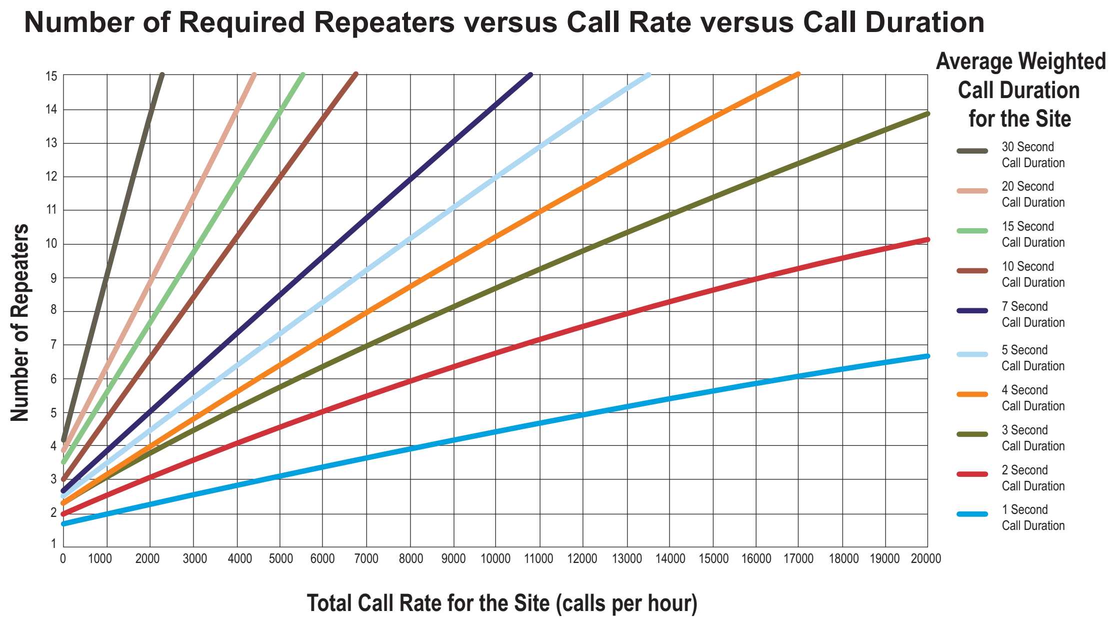
If each site is designed for less than 3% blocking, and the average number of sites in a call is 4.23, then the average system blocking would be better than 6.5%, $1 - (1\text{-}0.03)^{4.23}$. If a lower system blocking rate is desired, a lower site blocking rate must be used in the design, or the number of sites participating in a call, (that is, sites per PTT) must be lower.

Number of Required Trunking Repeaters

The number of repeaters can be determined, once the total call rate for the site and the average weighted call duration for the site have been determined. Figure 13 is created and illustrated using a grade of service for the site of 97%, that is 3% blocking rate.

Find the line that is closest to the calculated average weighted call duration and find where it crosses the calculated total call rate for the site on the x-axis. The corresponding location on the y-axis is the number of required repeaters.

Figure 13: Number of Required Repeaters versus Call Rate versus Call Duration



System Limitations

There are few system limitations that user needs to be aware of, when determining the number of trunked repeaters for a system, and their impact on the system can vary.

If any of these limitations are exceeded, the first step is to re-visit the predicted usage, and consider switching from a high to low usage profile. Location update rates may need to be lowered or offset to data revert repeaters. If usage is accurately captured, another nearby site may be required to offload some of the active users. Site preference can be utilized to evenly distribute the users and talkgroups.

Maximum Supported Number of Repeaters per Site

Capacity Max supports up to 15 trunking repeaters per site and up to 6 data revert repeaters, thus the total number of repeaters at the site cannot exceed 21.

Over the Air Call Rate Limit

The over the air call rate for the site should not exceed 12,000 cph. All inbound over the air call requests must be received on the inbound control channel. The inbound control channel can only receive 12,000 cph before performance begins to degrade. Once exceeded, the radio’s inbound requests begin to collide with each other until their retries are exhausted. Their requests are never received by the system and the radio provides a failure tone. At 16,000 cph 1% of all requests fail to reach the system.

Outbound Announcement Call Rate Limit

The total call rate for the site should not exceed 20,000 cph, and it includes over the air call rate plus over the wire call rate. Call grants must be announced to the radios over the air. The outbound control channel can only announce 20,000 cph before performance begins to degrade. Once exceeded, the time to respond to call requests decreases, and the time between announcing on-going calls increases, which increases late entry time. At 25,000 cph the average time between on-going call announcements increases past 2 seconds, and the average time to announce the second grant increases past 500 milliseconds, which decreases reliability and therefore voice access time.

Inbound Registration Limit

The inbound registration rate should not exceed 12,000 cph. The registration messages include: power on registration, power off de-registration, site affiliation messaging, and talkgroup affiliation like the

channel change. The registration messages are sent on timeslot two of the active control channel repeater. Similar to the inbound control channel on time slot one, the inbound registration channel on time slot two can only receive 12,000 registrations per hour before performance begins to degrade. Once exceeded, the radio’s inbound registrations begin to collide with each other, fail, retry, fail, retry, and so forth. Capacity Max system has a mechanism to handle a large spike in registrations, and it can process no more than 12,000 registrations per hour.

It is difficult to predict the precise number of registration messages that occur on a system. Historically, the number of registration messages that occur on a system is 1.7 times the **over the air voice call rate**. Therefore the over the air voice call rate should not exceed 7058 cph in order to keep the number of registrations below 12,000 cph.

Power on and off is a factor of 0.3, talkgroup change is 0.2, and roaming is 1.2. These total a multiplying factor of 1.7. This aligns with a typical or normal user operation, and it may need to be adjusted for some customers.

The 0.2 factor can be removed, if radios only have one talkgroup or very rarely change talkgroups, The 1.2 factor can be removed or halved, for a single site system or for systems with little to no roaming.

Chapter 6

Number of Data Revert Repeaters Selection

This chapter describes how to determine if and what type of radio to server data should be sent on a Enhanced GPS Revert Channel or a trunked channel and how to calculate the number of repeaters needed at a site to support a predicted data load.

Overview of Sending Data on Trunked or Revert Channels

The control channel supports up to 200 inbound messages per minute at its site. Inbound messages include requests from a radio for voice, text, location, and others. It also includes radio registration and affiliation messages if non-Motorola radios are deployed on the system. If the overall load is expected to be less than 200 inbound messages per minute, then all the data including radio to server data, should be sent on the trunked channels. If the overall load is expected to exceed 200 inbound messages per minute, then some if not all of the radio to server data should be sent on some type of Revert Channel. The first type of data load to examine is location data. If location data exceeds 200 inbound messages per min, then the location data needs to be sent on EGPS Revert channels.

The information determined in this section can be used as input to the Capacity Max System Capacity Estimator that is part of MOTOTRBO System Design Tools.

Enhanced GPS (EGPS) Revert Channel with IP Data

The Enhanced GPS (EGPS) Revert Channel with IP Data supports a large number of location updates (both indoor and GNSS), with rich location parameters. Table 24 illustrates the number of updates per minute a time slot supports for various Periodic Window Reservation and Window Size settings.

Table 24: The Number of Updates per Minute per Site

% Periodic Window Reservation	Radio to Server IP Data Messages per Minute per Site					
	Window = 5	Window = 6	Window = 7	Window = 8	Window = 9	Window = 10
90 %	180	150	128	112	100	90
75 %	150	125	107	93	83	75
60 %	120	100	86	75	66	60
45 %	90	75	64	56	50	45

Number of EGPS Revert channels required at a site for IP Data use:

(Location Radios) * (average location updates / minute) / (appropriate chart value)

For example, 200 radios updating every 0.5 minutes with a Periodic Window Reservation of 75% and a Window Size of 7.

(200 location radios) * (2 updates / minutes) / 107 = 3.74

For example, 4 channels (2 EGPS Revert repeaters) are necessary to support the data load. See the chapter on *Configuring Data Revert Channels, in the Capacity Max System Installation and Configuration manual*, for more detail on setting the Periodic Window Reservation. Third party

developers can provide the window size they require for their location server. The typical window size is 7 and the typical channel loading is 75%.

Enhanced GPS (EGPS) Revert Channel with High Efficiency Data

The Enhanced GPS Revert Channel with High Efficiency Data supports a very large number of GNSS location updates or Option Board data, but it supports a limited set of location parameters. Table 25 illustrates the number of updates per minute a time slot supports for various Periodic Window Reservation and Window Size settings.

Table 25: The Number of Updates per Minute per Site

% Periodic Window Reservation	Radio to Server High Efficiency Data Messages per Minute per Site	
	Window = 1	**Window = 2**
90 %	900	450
75 %	750	375
60 %	600	300
45 %	450	225

Number of EGPS Revert channels required at a site for High Efficiency Data use:

(Location Radios) * (average location updates / minute) / (appropriate chart value)

For example, 425 radios updating every 0.25 minutes with a Periodic Window Reservation of 90 % and a Window Size of 1.

(425 location radios) * (4 updates / minute) / 900 = 1.89

For example, 2 channels (1 EGPS Revert repeater) are necessary to support the data load. See the chapter on *Configuring Data Revert Channels, in the Capacity Max System Installation and Configuration manual*, for more detail on setting the Periodic Window Reservation. A window size of 1 is used when the server is connected through the MNIS data gateway, and a window size of 2 is used when the server is connected through a wireless control station.

Chapter 7

Application Deployment Options with MNIS Data Gateways

This chapter describes the deployment options for data applications and MNIS data gateways, and explains when a Capacity Max system requires more than one MNIS data gateway.

Application Deployment Options

A system could have multiple MOTOTRBO data applications, such as Text Messaging Service (TMS), Location Server Application, Over The Air Programming (OTAP), and any other special data applications.

A MNIS Data Gateway can support all these applications. However, it is important to confirm with the application vendor if any application restrictions apply.

A MNIS Data Gateway can be deployed in either of the following ways or a combination of both:

- MNIS Data Gateway and the data applications are deployed on the same computer.
- MNIS Data Gateway and the data applications are deployed on different computers.

Deploying the data applications and MNIS Data Gateway on the same computer is the simplest option. However, the computer must meet the total performance requirement for MNIS Data Gateway and any data applications deployed with it. For details, refer to the MNIS Data Gateway computer requirement specification.

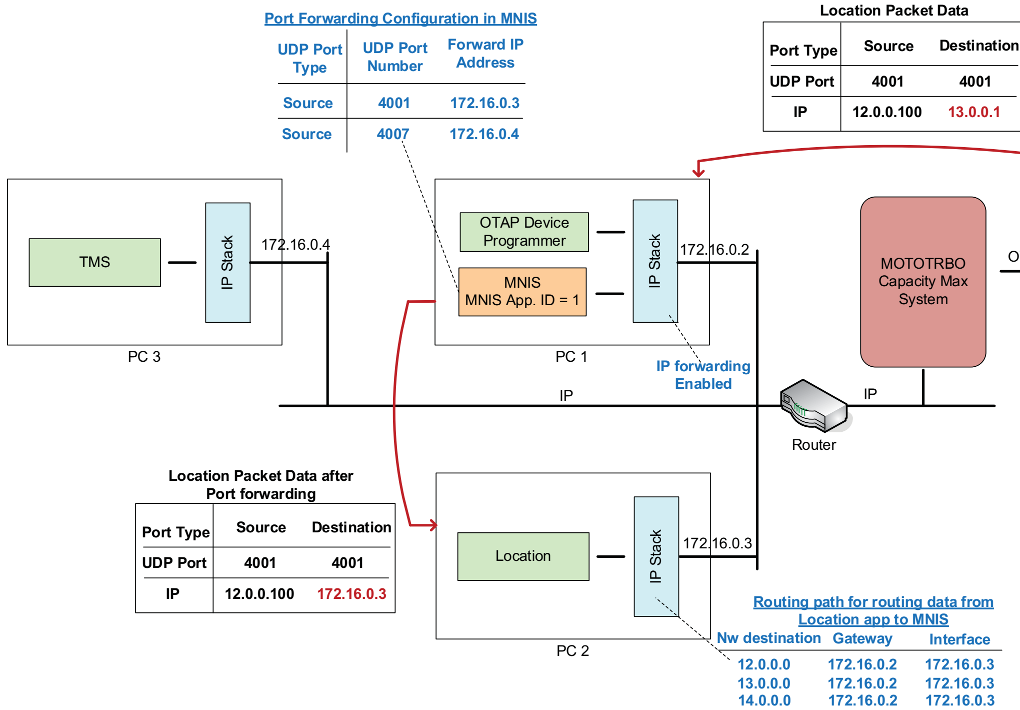
The data applications and MNIS Data Gateway can be deployed on different computers. The following are the possible reasons for this practice:

- The computer does not meet the total performance requirement of the MNIS Data Gateway and the data applications.
- The data application has restrictions of deployment with other applications.
- The data application is not a Windows application.
- To prevent unstable data application from interfering (such as operating system failure) with the MNIS Data Gateway operation.

Data messages to a talkgroup can be sent from an application only when the application and MNIS Data Gateway are deployed on the same computer. Only data messages to individual radios are supported in this configuration.

The MNIS Data Gateway supports data message port forwarding to facilitate deployment of data applications on separate computers, as shown in figure 14.

Figure 14: Deployment of Data Applications on Separate Computers



The MNIS Data Gateway is configured to forward location and text data messages from the radios to the computers with Location and Text applications respectively. The User Datagram Protocol (UDP) port type configured is the source port because the radios standard data services ports are fixed (with location = 4001 and Text = 4007).

The MNIS Data Gateway also allows selection of the destination port type. This option can be used for non-standard data services such as third-party raw data. Configuration of port forwarding is not required when the data application is deployed on the same computer as the MNIS Data Gateway. Therefore, no port forwarding configuration is required for the OTAP Device Programmer. The computers with the location and text applications require IP route configurations for routing messages from the data applications to the computer with MNIS Data Gateway.

Figure 14 shows the routes for data messages belonging to system CAI network IDs = 12, 13, 14. The computer with MNIS data gateway also requires IP routing enabled in its registry. For more information, see http://support.microsoft.com. This allows the data message from applications on the external PCs to be forwarded to the MNIS Data Gateway network interface.

MOTOTRBO radios are assigned addresses from Class A IP address space with default network IDs of 12, 13, 14. The talkgroups are assigned addresses from Multicast address space with default network ID of 224. These addresses are not globally unique and conflict with IP address domains of other enterprises. When applications are not deployed on the MNIS Data Gateway PC then the network routing must be configured to route data messages from applications on external PCs to the MNIS Data Gateway. To minimize network configuration it is recommended that the data application and the MNIS Data Gateway PC are connected to the same subnet. The subnet must not have any other PCs or devices that utilize radio IP addresses.

When an application must be remotely deployed, the following options should be considered:

- Select the application that supports a remote client, so the application can be deployed with the MNIS Data Gateway and the client is deployed at the remote location.
- Deploy another MNIS Data Gateway at the remote location with the application.

- Establish a VPN connection between the remote application and the MNIS Data Gateway subnet router.

While MNIS Data Gateway can support multiple data applications, only one instance of following types of application is supported per MNIS Data Gateway.

- TMS application.
- Location Server application when high efficiency data format is used for location updates.
- XCMP Data application using high efficiency data format.
- Battery Management application.
- Telemetry application.
- Option board raw data application.

This is a restriction per type of the application. So, two TMS applications are not supported by a MNIS Data Gateway, but a TMS application and a Telemetry application are supported by a MNIS Data Gateway.

In a Capacity Max system multiple location applications that are utilizing high efficiency data format can be deployed (with different data gateways). However, it should be noted that location updates (with high efficiency data format) from the radio are sent to all the location applications that are designated to receive location with high efficiency data format. It is assumed that the application discards updates from radios whose location it is not tracking. Similar situation is applicable when multiple XCMP Data applications that are utilizing high efficiency data format exist in the system.

Capacity Max supports up to five MNIS Data Gateways. Typically, multiple MNIS Data Gateways are required when two or more agencies are sharing a Capacity Max system and they require data applications. When the number of such agencies exceeds five then the application which can support remote clients should be considered. Such applications should support data access, for the agencies, from a single central MNIS Data Gateway.

The MNIS Data Gateway supports MOTOTRBO systems such as the Single Site, IPSC, Capacity Plus and Capacity Max. It does not support multiple systems together. The MNIS Data Gateway operates in the system mode based on the selected active configuration. See the chapter on *MNIS Data Gateway Configuration in Capacity Max, in the Capacity Max Installation and Configuration Manual.*

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Chapter 8

Number of VRC Gateways and Talkpaths Selection

This chapter provides guidelines to determine the number of VRC Gateway and number of active talkpath licenses required by a Capacity Max system.

Overview

A Capacity Max system supports up to five VRC Gateways, where each VRC Gateway can have a redundant VRC Gateway.

A Capacity Max system may require multiple VRC Gateways in the following scenarios:

- If a Capacity Max system is shared by a set of agencies, where each agency has its own set of voice applications. In this scenario, a separate VRC Gateway is required for each agency because either they are at different locations or they want independent deployment of their VRC Gateway and applications.
- If the total capacity required by the system is greater than what is provided by one single VRC Gateway.

VRC Gateway Capacity

The capacity of a VRC gateway is shown in the following table. If any of these capacities are exceeded then one or more additional VRC gateways are required.

For example, if a system requires multiple voice applications and the total quantity is greater than ten then one or more additional VRC gateways are required. Likewise, if the deployment calls for the number of groups, radio IDs, radio ID ranges per phone or recorder application to exceed the gateway capacity then additional VRC gateways are required. If the number of talkpaths exceeds 100, then additional VRC gateways are required.

Table 26: VRC Gateway Capacity

Capacity Parameter	VRC Gateway Max Capacity	Assumptions
Number of applications[1] (clients)	10	See the following Note.
Number of Groups the applications affiliates.	1000	On average, three applications subscribe to same group.
Number of radio IDs the application registers.	5000	
Phone or Recorder subscribed radios	32 radio ID ranges per application	
[2]Number of calls (voice call session) that are active concurrently and the application is required to participate	100 active talkpaths (or calls)	On average, a total of six sites (RF or VRC Gateway sites) plus applications are participating in the call.

Notes:

[1]Wireline voice applications (for example, voice dispatch, voice recorders, phone gateway) and non-voice wireline applications (only support radio commands) are generically referred to as application in this section. Wireline voice dispatch applications normally have a client-server architecture, where the dispatch position clients connect to the server. The application server connects with the VRC Gateway. In this case, the server is counted as one application. A redundant server application may be counted as one additional application when it remains connected with the VRC gateway during stand-by (or inactive) mode. Likewise multiple instances of an application (or application servers) connecting with the VRC gateway are counted as additional applications.

[2]When a VRC gateway has reached its talkpath license limit, and if a console at the VRC gateway is starting a new call, then the call request is rejected; otherwise the call is setup but is not forwarded to the voice application.

Active Talkpaths

A talkpath is the sourcing and receiving of one voice call to a VRC Gateway. This section provides guidelines to estimate the number of VRC gateway talkpaths required in the system. This number divided by the number of talkpaths a VRC gateway supports is the number of VRC Gateways required to support those talkpaths. Exceeding any of the capacities listed in the VRC Gateway Capacity section may require additional VRC gateways.

The maximum number of VRC gateway talkpaths that a system would ever possibly require is if every trunked resource in the system was simultaneously utilized for a local site voice call and every one of those calls was monitored by a voice application. This would essentially be the number of trunking repeaters in the system multiplied by two, to account for each logical channel (that is, timeslot), and then subtract a control channel for each site. See Number of Trunking Repeaters Calculation on page 111, for more information on calculating the number of trunking repeaters required per site and therefore in the system.

Ultimate Peak Number of Active Talkpaths = ((Trunked Repeaters in the System x 2) - # of Sites).

Although, this is a highly unlikely scenario since multiple trunked resources at different sites commonly participate in group and individual voice calls. In addition, not all group calls and individual calls are monitored by voice applications. Since the number of talkpaths is licensed, a better estimation may be desirable.

The first step is to make a reasonable estimation of the number of simultaneous voice calls that a system may experience, and second is to determine how many of those voice calls are monitored by voice applications.

Simultaneous Voice Calls

As described in “Active Talkpaths”, the maximum number of simultaneous voice calls that a system would ever possibly experience is if every trunked resource in the system was simultaneously utilized for a local site voice call and every one of those calls was monitored by a voice application.

If every talkgroup was affiliated with two sites, then the total number of simultaneous voice calls in the system would be the number of traffic channels in the system divided by two. The section Number of Users and their Usage Prediction on page 111 describes the prediction of the average number of sites participating in a call. This is important in calculating the number of trunking repeaters, and also important in estimating simultaneous voice calls. The number of simultaneous voice calls can be calculated by dividing the number of traffic channels in the system by predicted average sites per call.

Simultaneous Voice Calls = Ultimate Peak Number of Active Talkpaths / Average Sites Per Call.

The following table summarizes the typical weighted average sites per call versus the number of sites in the system.

Table 27: Typical Weighted Average Sites per Call

Number of Sites	Average Sites per Call
1	1.00
2	1.48
3	1.91
4	2.30
5	2.65
6	2.95
7	3.21
8	3.43
9	3.61
10	3.77
11	3.90
12	4.01
13	4.10
14	4.17
15	4.23

Simultaneous Voice Calls Monitored by Voice Applications

The number of required talkpaths is equal to the number of simultaneous voice calls monitored by voice applications. If every voice call is monitored by a voice application, then the number of required talkpaths is equal to the number of simultaneous voice calls calculated in “Simultaneous Voice Calls”.

To properly calculate the number of required talkpaths, the number of simultaneous voice calls monitored by voice applications must be predicted. Typically, most talkgroups are monitored by voice consoles or recorded by a voice recorder. Often individual calls are made to voice consoles and sometimes radio to radio individual calls recorded by a voice recorder.

The total number of simultaneous voice calls is the summation of the number of simultaneous talkgroup calls, and the number of simultaneous individual calls. The percent of each should be estimated. A typical profile is 90% group calls and 10% individual calls.

The percent of the simultaneous group voice calls routed to a console or logged to a logging recorder should be estimated. Typically, most talkgroup traffic is either routed to a console or logged (90%), and only a few are not (10%).

The number of simultaneous individual calls is the summation of the number of simultaneous radio to console or console to radio individual calls, and the number of simultaneous radio to radio individual calls.

The percent of each should be estimated. A typical profile may be 90% radio to radio and 10% to/from the console. The percent of the simultaneous radio to radio individual calls that are logged to a console should be estimated. When logging radio to radio calls, typically most are logged (90%), and only a few are not (10%). The percentages can be multiplied to create a percentage of the number of

simultaneous voice calls for each category as shown in the following table. For example, 10% x 90% x 90% = 8.1%.

Table 28: Number of Simultaneous Voice Calls

Number of Simultaneous Talkgroup Calls (90%)		Number of Simultaneous Individual Calls (10%)		
		Number of Simultaneous Radio to Radio Individual Calls (90%)		
Number of Group Calls to/from Console OR Logged (90%)	Number of Group Calls NOT to Console or NOT Logged (10%)	Number of Radio to Radio Individual Calls Logged (90%)	Number of Radio to Radio Individual Calls NOT Logged (10%)	Number of Simultaneous Radio to/from Console Individual Calls (10%)
81%	9%	8.1%	0.9%	1%

The number of talkpaths required = number of simultaneous group voice calls to/from a console or that are logged + the number of simultaneous radio to radio individual calls that are logged + the number of simultaneous radio to/from the console individual calls. Therefore this is 90.1% (81%+8.1%+1%) of the number of simultaneous voice calls.

For example, if a system has five sites each with 50 repeaters, then there are 50 total trunked repeaters in the system. This equates to 36 (((50x2)-5)/2.65) simultaneous voice calls. If assuming the above typical usage profile, the number of talkpaths required is 90.1% (81%+8.1%+1%) of 36, which is 33 talkpaths. Since one MNIS VRC Gateway supports 100 talkpaths, only one MNIS VRC gateway is required.

Additional Notes on Talkpath Estimations

Additional considerations for estimating the number of talkpaths for a system are as follows:

- If multiple applications are affiliating to the same group, then the application should affiliate the group from the same VRC gateway. If such an arrangement is not possible, then adjust upwards the talkpaths by ‘n’ (n=1, 2, …) for every group voice call that is being routed to ‘n’ additional VRC gateways.
- The number of group/individual voice calls should also include phone calls.
- The number of talkgroups voice applications are affiliating should be known.
- Logging recorders affiliate to the group for recording the group voice call.
- Phone applications affiliate to the group if it is initiating the group phone call.
- If a logging recorder and a voice application are not using the same VRC gateway, then add the number of simultaneous radios to/from the console individual calls to the number of talkpaths.
- This calculation does not account for any console to console communication that does not utilize a trunked resource.
- It is not unusual to adjust the number of talkpaths upwards by (10-20%) to accommodate any unforeseen peak scenarios or incorrect assumptions.

Talkpath Licenses and VRC Gateway

The system is configured to route calls (group, phone and private calls to be recorded, allowed sites for application radio IDs) to the VRC gateway. In case of multiple VRC gateways, the configuration should be that the peak loading of a VRC gateway does not exceed the maximum talkpath capacity of the

VRC gateway. The talkpath license should be allocated to the VRC gateway based on their call loading profile.

The same number of talkpath license should be allocated to the primary and redundant VRC Gateway. If a voice application is required to receive calls from multiple VRC gateways then contact the application vendor to confirm if the application supports this feature. Confirm with the application vendor the number of calls their application can support concurrently. The information determined in this section can be used as input to the Capacity Max VRC Gateways and License Calculator that is part of MOTOTRBO System Design Tools.

When redundant VRC gateways are not required:

- Number of VRC Gateway Licenses = Number of VRC ‘Primary’ Gateways.
- Number of talkpath License = Talkpaths.

When each primary VRC gateway has a redundant VRC gateway:

- Number of VRC Gateway Licenses = Number of VRC ‘Primary’ Gateways x 2
- Number of Talkpath Licenses = Talkpaths x 2

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Chapter 9

Network Components for Capacity Max IP Connectivity

This chapter describes the requisite network components providing IP Connectivity for a Capacity Max system.

Overview

A Capacity Max System comprises many devices such as the Repeaters, Capacity Max System Servers, MNIS VRC Gateways, MNIS Data Gateways, Data Application Servers, and Console Gateways, that are located at one or more physical locations. The Capacity Max System's architecture relies upon IP Routing (OSI layer 3) and Ethernet switching (OSI layer 2) to connect the various devices within a Capacity Max System. This chapter describes requisite network components providing IP Connectivity for a Capacity Max System.

Physical Location Requirements

Every physical location, including single site systems, in a Capacity Max system requires an Ethernet switch and an IP router. Multi-site systems additionally require WAN links to provide IP connectivity between physical locations.

Because Capacity Max systems manage many features and capabilities through software licensing, it is highly recommended that all Capacity Max systems (including single-site systems) have at least a temporary connection to a public Internet to be able to obtain the necessary licenses during installation and future system upgrades and expansions.

If a connection to the public Internet is either not possible or not desirable (for example, due to enhanced system security), when new licenses are installed, the Radio Management server must be physically removed from the system and taken to a location that has access to the public internet.

Ethernet Switch and IP Router Common Characteristics

The following table identifies both required and recommended characteristics common to the Ethernet switch and IP router for a Capacity Max system.

Table 29: Required and Recommended Characteristics

Capability Description	Required	May Be Needed	When Needed?
Fully Managed		X	When ability to remotely troubleshoot or configure a network device is desired.
SNMPv3		X	When System Advisor is used.
IEEE 802.1q VLAN Tagging		X	When multiple subnets are needed at a physical location for more than one RF sites or more than one gateways or any combination of sites and gateways at the physical location.

Table continued…

Capability Description	Required	May Be Needed	When Needed?
Differentiated Services (DiffServ) for Quality of Service (QoS) management		X	When classifying and managing network traffic for quality of service (QoS) is desired.

Ethernet Switch Characteristics

The following table identifies required and recommended characteristics for the Ethernet switch for a Capacity Max system.

Table 30: Required and Recommended Characteristics for the Ethernet Switch

Capability Description	Required	May Be Needed	When Needed?
IEEE 802.3u 100BASE-TX Interfaces (for connection to Repeaters and Capacity Max System Server)	X		Always.
Rapid Spanning Tree Protocol (RSTP, IEEE 802.1w)		X	When more than one Ethernet switch is used at a physical location.
IPv4	X		Always.
Port Mirroring (SPAN or RSPAN or RAP) capability	X		Always.
Port Security		X	When increased network security is desired.
MAC port lockdown		X	When increased network security is desired.
Simple Network Time Protocol (SNTP, RFC 4330)		X	When automatically synchronizing time of day across all network devices is desired

IP Router Characteristics

The following table identifies required and recommended characteristics for the IP router for a Capacity Max system.

Table 31: Required and Recommended Characteristics for the IP Router

Capability Description	Required	May Be Needed	When Needed?
IEEE 802.3u 100BASE-TX Interfaces	X		Always.

Table continued…

Capability Description	Required	May Be Needed	When Needed?
2 Interfaces, minimum	X		Always.
Rapid Spanning Tree Protocol (RSTP, IEEE 802.1w)		X	When more than one Ethernet switch is used at a physical location.
Open Shortest Path First (OSPF, RFC 2328)		X	When Dynamic Direct Hub-Hub VPN Tunneling such as ADVPN or DMVPN is used. Motorola recommends using dynamic tunneling in all Capacity Max deployments for ease of network configuration.
IPv4 (LAN-side and WAN-side)	X		Always.
Inter-VLAN Routing Capability		X	When multiple subnets are needed at a physical location.
Generic Routing Encapsulation (GRE, RFC 2784)		X	When VPN is used between physical locations (required when using public ISP).
Dynamic Direct Hub-Hub VPN Tunneling such as ADVPN or DMVPN		X	When VPN is used between physical locations (required when using public ISP).
IPsec (RFC 4301)		X	When VPN is used between physical locations and increased security is desired.
Network Time Protocol (NTP, RFC 5905)		X	When automatically synchronizing time of day across all network devices is desired.

WAN Links (Site Links)

Internet Service Providers (ISP) provide a range of technologies such as dial-up, Digital Subscriber Line (DSL, typically Asymmetric DSL), Data Over Cable Service Interface Specification (DOCSIS) cable modem, broadband wireless access, Integrated Services Digital Network (ISDN), Frame Relay, Satellite Internet access, and so on, which can be used for Capacity Max WAN links. The Capacity Max WAN links cannot be based on a dial-up connection (due to low link bandwidth) or Satellite Internet access (due to large delay).

A site's link bandwidth must be estimated and once the estimated bandwidth is known, an appropriate WAN link technology may be selected, and agreements can be negotiated with the WAN link provider and appropriate equipment can be procured in accordance with the WAN provider's recommendation. To minimize configuration issues between the WAN equipment (for example, modem) and the network equipment (for example, IP router) at a physical location, it is recommended that both the WAN equipment and network equipment provide an IEEE 802.3u 100BASE-TX Interface set to auto-negotiate speed, duplex, and crossover (Auto MDI-X). If auto-negotiate is not used, then the speed, duplex, and crossover must be manually configured correctly in each device. If DOCSIS is used, DOCSIS version 3.1, or newer, is recommended.

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Chapter 10

IP Bandwidth Per Site Requirement for Capacity Max

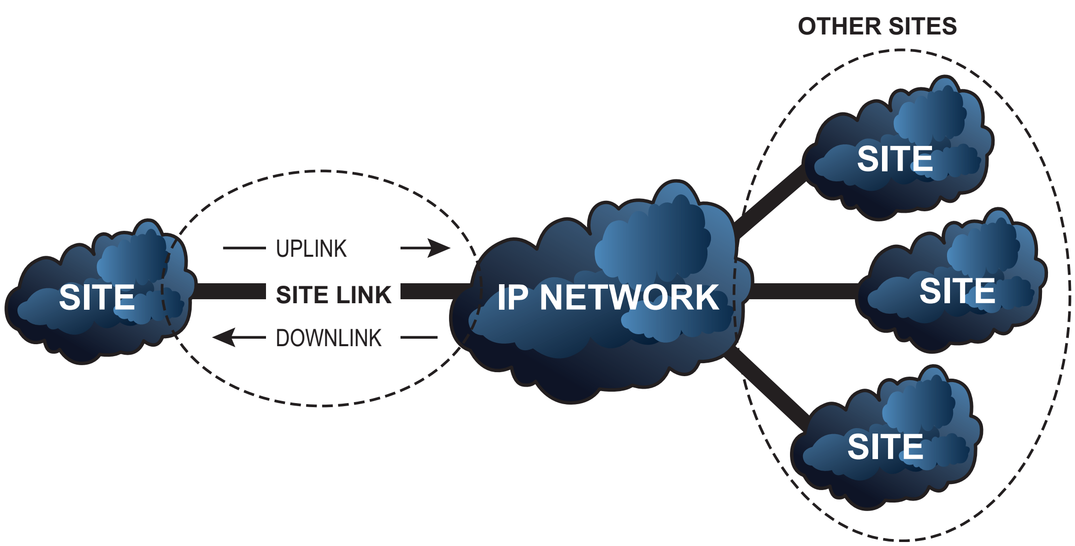
This chapter describes how to estimate link bandwidth requirements for a site, and covers both uplink and downlink bandwidth requirements.

Overview

A physical location containing Capacity Max equipment must have IP connectivity through a wide area network to other physical locations, or sites, in the system. An Internet Service Provider commonly provides IP connectivity through a public internet, but private point-to-point links may provide connectivity as well. It is important that a site link provides enough bandwidth to handle the expected peak volume of data that will flow in either direction on the site link. “Uplink” refers to data flowing from a site towards the other sites in a system and “downlink” refers to data flowing in the opposite direction. Uplink and downlink bandwidth requirements are determined independently and are usually different.

User calculates bandwidth requirements for each site link of a Capacity Max system independently. Figure 15 is a reference model for determining link bandwidth requirements for a single particular site belonging to a Capacity Max system. The Capacity Max system is broken into three pieces: a site (far left side of diagram), a site link whose bandwidth requirements will be estimated, and the rest of the system, which includes the IP network and all other sites, for this analysis.

Figure 15: Link Bandwidth Requirement Per Site



Factors Influencing the Required Bandwidth Amount on a Site Link

The following are factors that influence the amount of bandwidth required on a site link:

- The number of subscribers present at the site
- The number of subscribers at other sites
- The average number of other repeater sites associated with talkgroup calls

- The number of trunked repeaters present at the site
- The number of trunked repeaters at other sites
- The number and type of data revert repeaters present at the site
- The number of System Advisor server applications present at the site
- The number of System Advisor server applications at other sites
- The number of System Advisor client applications present at the site
- The number of System Advisor client applications at other sites
- The number of Radio Management server applications present at the site
- The number of Radio Management server applications at other sites
- The number of Radio Management client applications present at the site
- The number of Radio Management client applications at other sites
- The number of MNIS VRC Gateways (specifically talkpaths) present at the site
- The number of MNIS VRC Gateways (specifically talkpaths) at other sites
- The number of MNIS Data Gateways present at the site
- The number of MNIS Data Gateways at other sites
- The number of call monitoring applications present at the site
- The number of call monitoring applications at other sites
- The number of Trunk Controllers present at the site

Other factors that influence the amount of bandwidth required on a site link include the type of IP tunneling used, as follows:

- “GRE Tunneling” is the minimum tunneling requirement when using a public internet to provide site link connectivity and is used as a reference baseline for Capacity Max link bandwidth calculations. “GRE Tunneling” provides a similar level of security as other MOTOTRBO systems, such as IP Site Connect and Capacity Plus, and does not provide data integrity protection, sender authentication, prevention of replay attacks, or confidentiality protection; however, when MOTOTRBO privacy services are enabled in the radios and gateways, the MOTOTRBO privacy service does provide confidentiality protection for end-user payload as packets flow across the public internet.
- “GRE Tunneling w/IPsec Authentication Header” may be used when data integrity protection, sender authentication, and prevention of replay attacks are desired, but this tunneling mode increases the link bandwidth requirements about 25% above the baseline “GRE Tunneling” requirements. “GRE Tunneling w/IPsec Authentication Header” does not provide confidentiality protection of packets as they flow across the public internet; however, when MOTOTRBO privacy services are enabled in the radios and gateways, the MOTOTRBO privacy service does provide confidentiality protection of end-user payload as packets flow across the public internet.
- “GRE Tunneling w/IPsec Encapsulating Security Payload” may be used when data integrity protection, sender authentication, prevention of replay attack, and confidentiality protection is desired and this tunneling mode increases the link bandwidth requirements about 30% above the baseline “GRE Tunneling” requirements. “GRE Tunneling w/IPsec ESP” provides confidentiality protection of both end-user payload and other Capacity Max system control information as packets flow across the public internet regardless of whether MOTOTRBO privacy services are enabled in subscribers or gateways.
- “No Tunneling” may be used only when private internets provide inter-site connectivity; however, “GRE Tunneling” is still recommended when using a private internet so that the recommended Capacity Max IP Plan may be easily used. The “No Tunneling” mode decreases the link bandwidth requirements about 12% below the baseline “GRE Tunneling” requirements.

- “GRE Tunneling w/IPsec Encapsulating Security Payload and IPsec Authentication Header” is rarely used in practice because of the increased overhead that Authentication Header would incur for packets that are already adequately protected by Encapsulating Security Payload. This tunneling mode increases the link bandwidth requirements about 40% above the baseline “GRE Tunneling” requirements, when this combination is used.

The available tunneling modes are summarized in the following table along with their capabilities and link bandwidth requirements relative to the baseline.

Table 32: Tunneling Modes Capabilities and Link Bandwidth Requirements

Tunnel Type	Data Integrity Protection	Sender Authentication	Replay Prevention	Confidentiality Protection	Site Link Bandwidth Impact
No Tunneling	No	No	No	No	Baseline - 12%
GRE Tunneling	No	No	No	No	Baseline
GRE w/IPsec AH[1]	Yes	Yes	Yes	No	Baseline + 25%
GRE w/IPsec ESP[2]	Yes	Yes	Yes	Yes	Baseline + 30%
GRE w/IPsec AH and ESP	Yes	Yes	Yes	Yes	Baseline + 40%

[1] IPsec AH Assumes use of Secure Hash Algorithm (SHA) Hash Message Authentication Code (HMAC)

[2] IPsec ESP Assumes use of Triple-DES and Secure Hash Algorithm (SHA) Hash Message Authentication Code (HMAC)

The type of authentication and / or encryption algorithms used for IPsec also impact the amount of bandwidth required on the site link. As indicated in the footnotes, the above table assumes that Authentication Header (AH) uses Secure Hash Algorithm (SHA) for the Hash Message Authentication Code (HMAC), and Encapsulating Security Payload (ESP) uses Triple-DES (or DES) for Confidentiality and Secure Hash Algorithm (SHA) for Hash Message Authentication Code (HMAC).

This System Planner provides a collection of graphs for common site and system configurations, for an initial estimate of site link bandwidth requirements; while for a more precise estimate, a site link bandwidth estimation tool is available that allows each of the identified influencing items to be specified for a specific link estimate.

Site Link Bandwidth Requirements for Repeater Traffic

To estimate the required Site Link bandwidth for repeater traffic, all the charts illustrated in section below assumes the following, unless noted otherwise:

- No redundant repeaters at site
- 1 MNIS VRC Gateway located in the system but at another site
- 1 MNIS Data Gateway located in the system but at another site
- 1 System Advisor server application located in the system but at another site
- 1 call monitoring application located in the system but at another site

- The number of data revert repeaters at a site varies automatically in accordance with the data revert type and estimated subscriber load. Refer to Capacity Max Data Revert Channel on page 35, for recommendations on the number of GPS revert repeaters.

Assume 100 subscribers per trunked channel which is also know as the timeslot, and all subscribers use GPS.

Enhanced GPS Revert Channel for IP Data: 1 minute update period per subscriber. Window size of seven, 90 % loaded, that is 128 updates per minute per timeslot.

Enhanced GPS Revert Channel for High Efficiency Data: 0.5 minute update period per subscriber. Window size of one, 90 % loaded, that is 900 updates per minute per timeslot.

- The number of sites associated with a talkgroup call varies per the recommendations identified in Number of Trunking Repeaters Selection in Capacity Max on page 109.
- GRE Tunneling is assumed. For other tunneling types, see the table above to determine the amount by which to scale the needed bandwidth.

GRE Tunneling, Uplink Bandwidth Requirement

The following charts correspond to different GPS revert options such as, no GPS, Enhanced GPS, and High Efficiency GPS.

NOTICE: These charts assume that GRE Tunneling is being used. The value indicated in the chart needs to be adjusted by the amount shown in the previous table, if a different tunneling mode is used.

Figure 16: No GPS

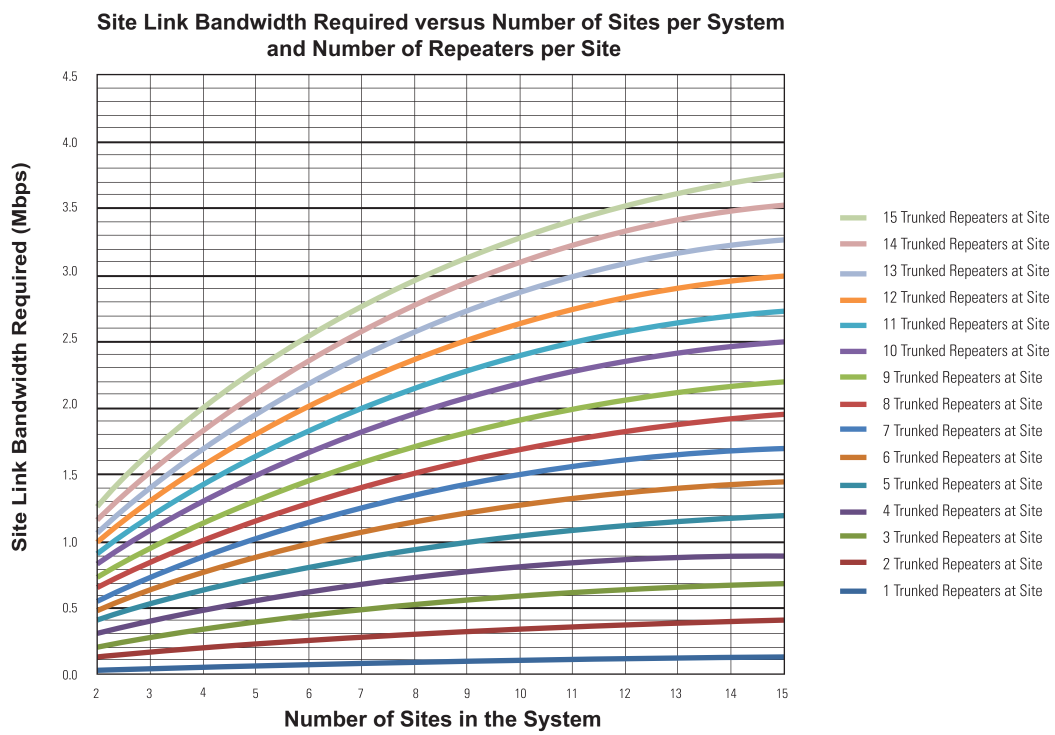


Figure 17: Enhanced GPS Revert Channel for IP Data

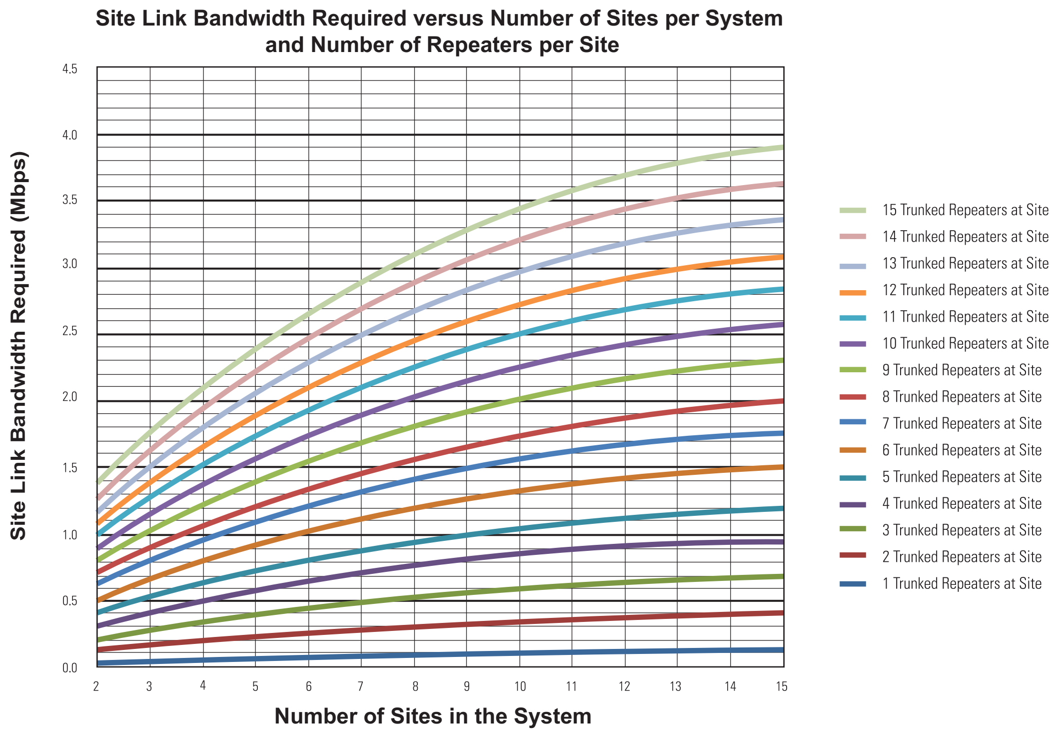


Figure 18: Enhanced GPS Revert Channel for High Efficiency Data

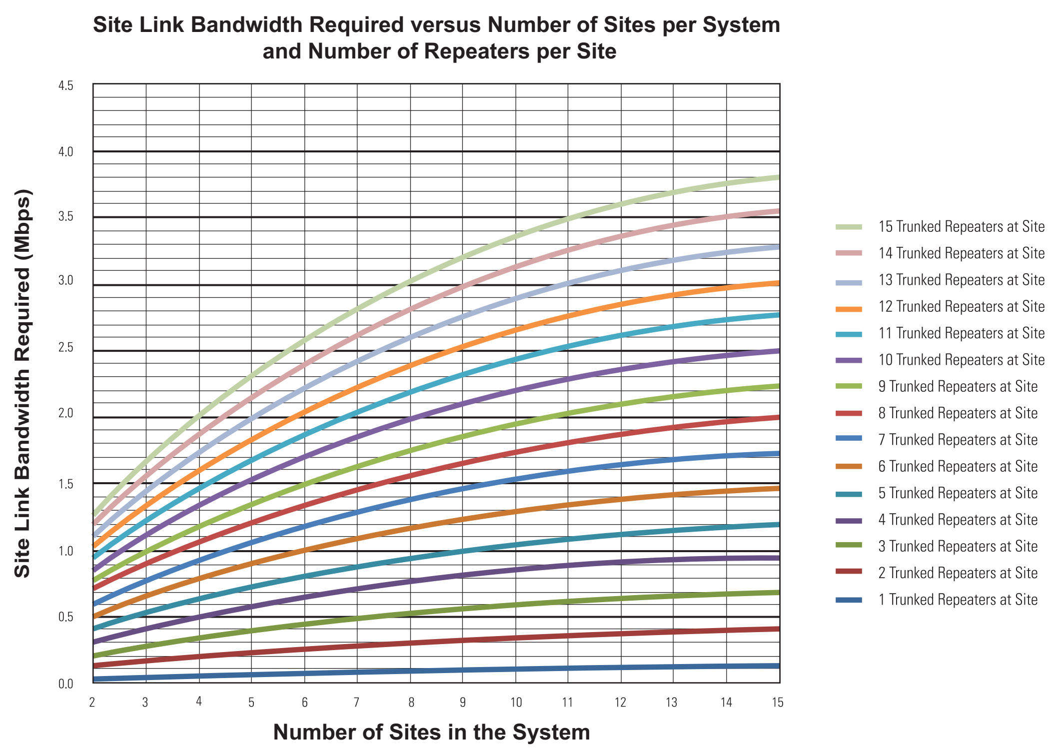
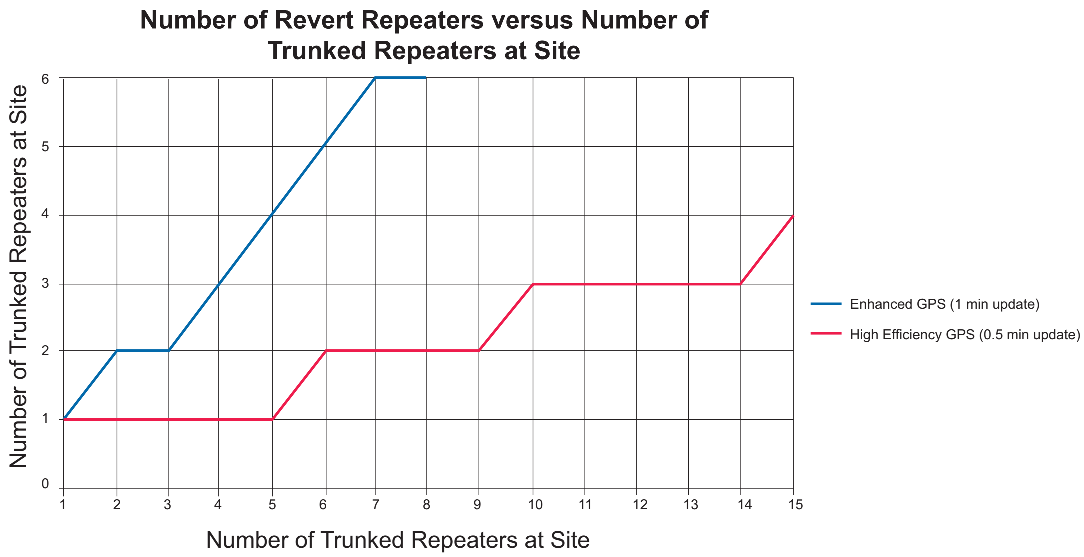


Figure 19: The Number of GPS Revert Repeaters Assumed in above Charts



GRE Tunneling, Downlink Bandwidth Requirement

The downlink bandwidth requirements are not dependent upon the number of Enhanced GPS with IP Data or Enhanced GPS with High Efficiency Data repeaters located at a site. The following table specifies the downlink bandwidth required for a site with a given number of trunked repeaters. The downlink bandwidth roughly follows the equation 30.2 kbps x NumberOfTrunkedChannels + 12 kbps, and following all of the assumptions stated previously.

Table 33: The Downlink Bandwidth Required for a Site

Number of Trunked Repeaters at Site	Downlink Bandwidth (Mbps)
1	0.039
2	0.099
3	0.159
4	0.220
5	0.280
6	0.340
7	0.400
8	0.461
9	0.521
10	0.581
11	0.642
12	0.702
13	0.762
14	0.823
15	0.883

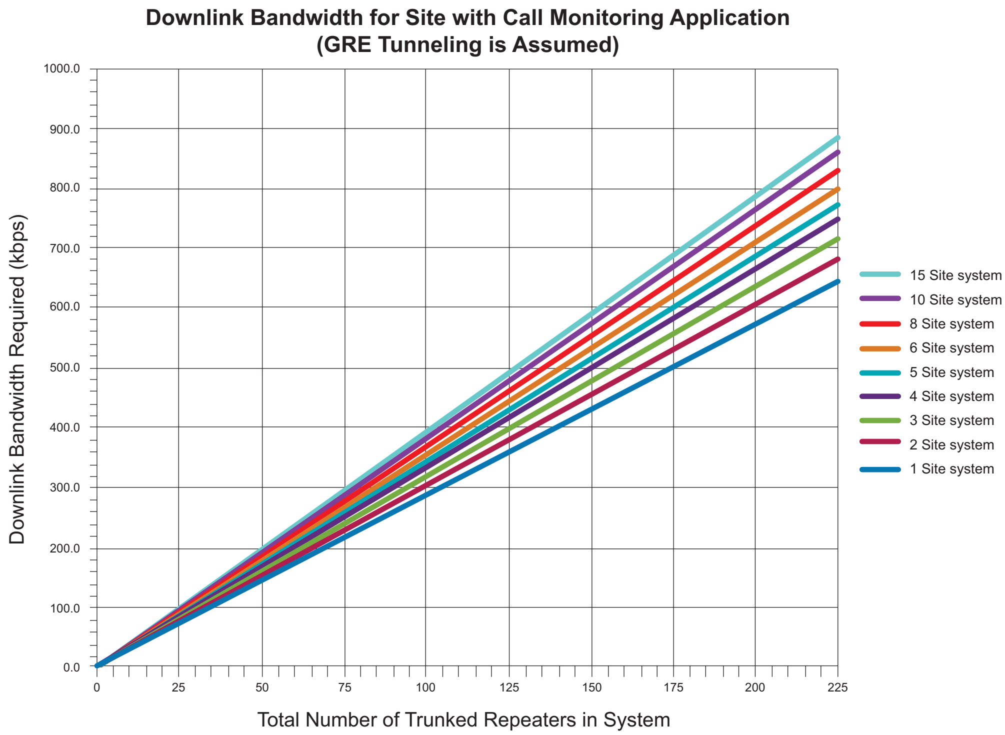
Bandwidth Requirements Estimation and Examples

The information determined in this section can be used as input to the Capacity Max Site Link Calculator that is part of MOTOTRBO System Design Tools.

Estimating Site Link Bandwidth Requirements for Sites Having a Call Monitoring Application

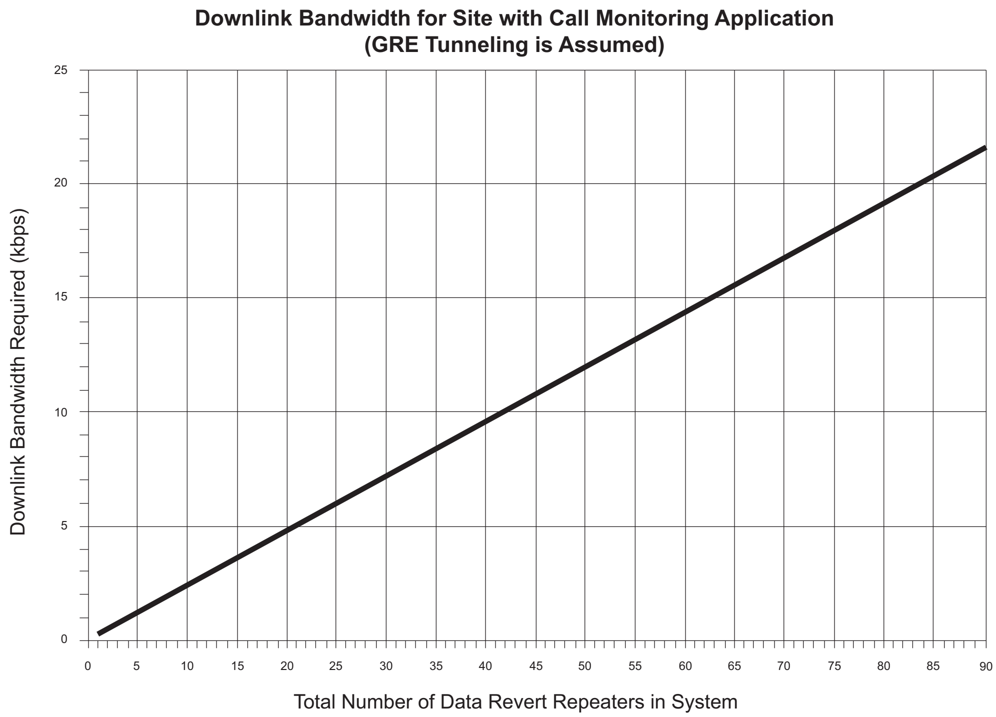
When a call monitoring application (for example, System Advisor server) is located at a site, the *downlink* bandwidth requirements at that site should be increased by the amounts indicated in the following chart per call monitoring application instance as a function of the total number of trunked repeaters and sites in the system.

Figure 20: Downlink Bandwidth for Site with Call Monitoring Application



The *downlink* bandwidth requirements at that site should be further increased by the amounts indicated in the following chart per call monitoring application instance as a function of the total number of data revert repeaters in the system.

Figure 21: Downlink Bandwidth for Site with Call Monitoring Application



NOTICE: When a call monitoring application (for example, System Advisor server) is located at a site, the *uplink* bandwidth requirements do not need to be adjusted.

Estimating Site Link Bandwidth Requirements for Sites Having Radio Management Clients

When a Radio Management client is located at a site that does not have a Radio Management server, the *downlink* and *uplink* bandwidth requirements at that site should be increased by the following amounts per Radio Management client instance:

- GRE tunneling: 0.055 Mbps (55 kbps)

Estimating Site Link Bandwidth Requirements for Sites Having Radio Management Servers

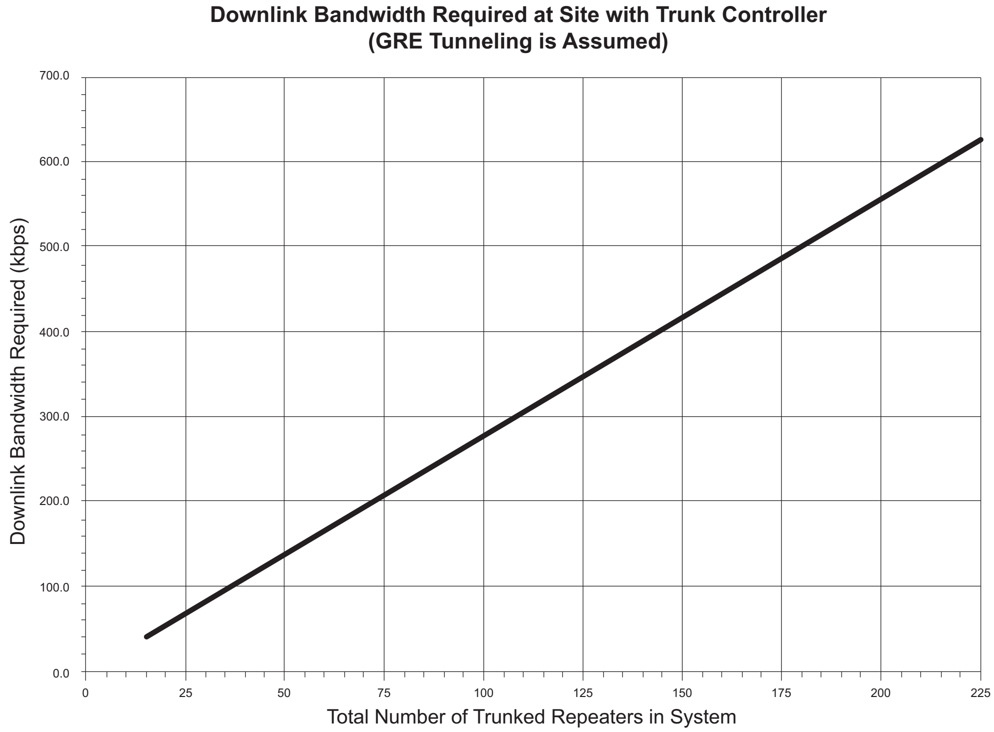
When a Radio Management server is located at a site and Radio Management clients are located at other sites, the *downlink* and *uplink* bandwidth requirements at the site with the Radio Management server should be increased by the following amounts per remote Radio Management client instance:

- GRE tunneling: 0.055 Mbps (55 kbps)

Estimating Trunk Controller Link Bandwidth Requirements

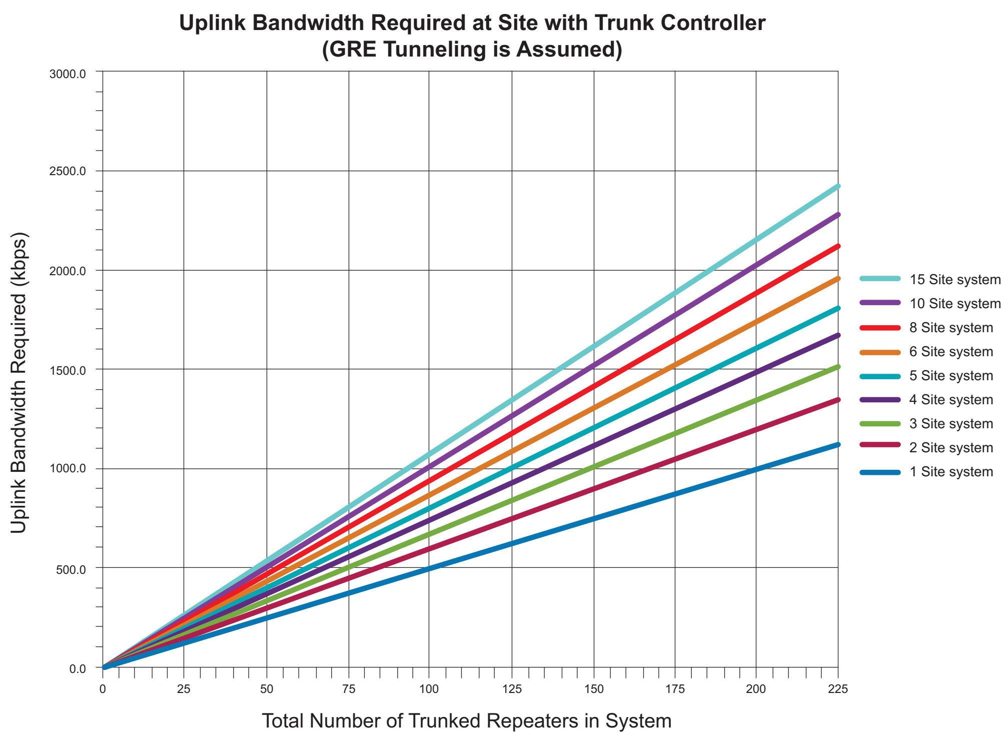
When one or more trunk controllers are located at a site, the *downlink* bandwidth requirements at that site should be increased by the amounts indicated in the following chart as a function of the total number of trunked repeaters in the system.

Figure 22: Downlink Bandwidth at Site with Trunk Controller



When one or more trunk controllers are located at a site, the *uplink* bandwidth requirements at that site should be increased by the amounts indicated in the following chart as a function of the total number of trunked repeaters and sites in the system.

Figure 23: Uplink Bandwidth at Site with Trunk Controller



NOTICE: The above charts describing uplink and downlink bandwidth for the trunk controller assume there is one MNIS VRC Gateway, one MNIS Data Gateway, and one System Advisor server in the system.

Estimating Site Link Bandwidth Requirements for Sites Having System Advisor Clients

When a System Advisor client is located at a site that does not have a System Advisor server, the *downlink* and *uplink* bandwidth requirements at that site should be increased by the following amounts per System Advisor client instance:

- GRE tunneling: 0.055 Mbps (55 kbps)

Estimating Site Link Bandwidth Requirements for Sites Having System Advisor Servers

When a System Advisor server is located at a site and System Advisor clients are located at other sites, the downlink and uplink bandwidth requirements at the site with the System Advisor server should be increased by the following amounts per remote System Advisor client instance:

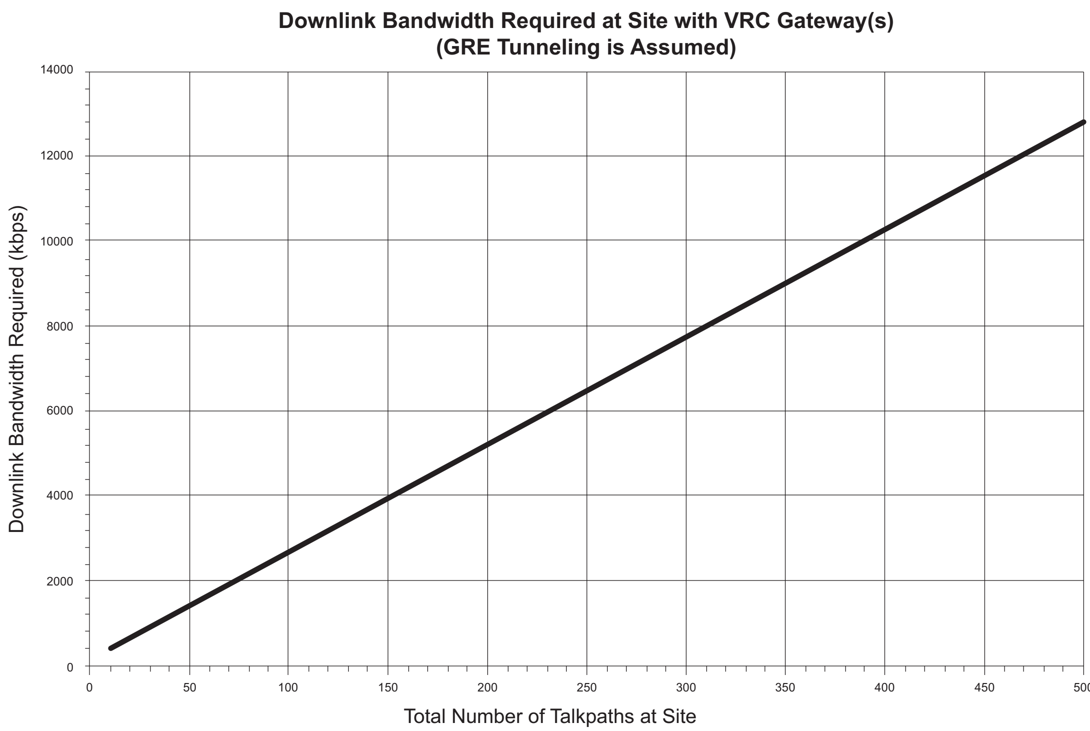
- GRE tunneling: 0.055 Mbps (55 kbps)

NOTICE: If the System Advisor server is receiving call monitoring traffic, bandwidth for the call monitoring traffic must additionally included. See the previous section on *Estimating Site Link Bandwidth Requirements for Sites Having a Call Monitoring Application*.

Estimating MNIS VRC Gateway Link Bandwidth Requirements

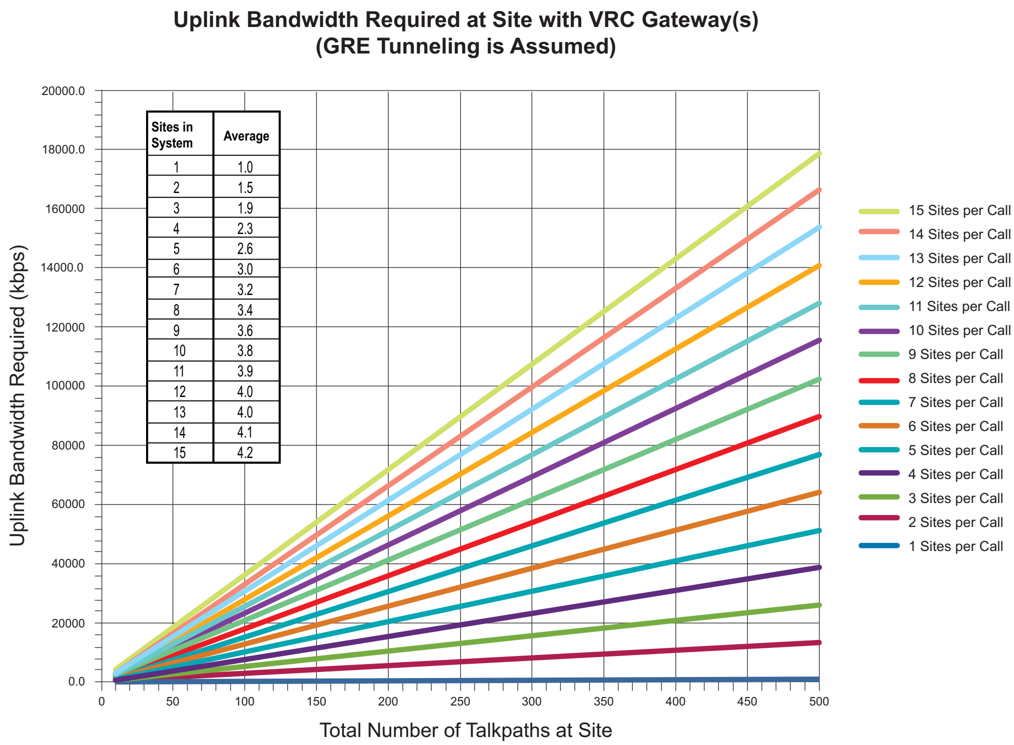
When a MNIS VRC Gateway is located at a site, that site's *downlink* bandwidth requirements should be increased by the following amounts as a function of total number MNIS VRC gateway talkpaths at a site.

Figure 24: Downlink Bandwidth at Site with VRC Gateway(s)



When a MNIS VRCGateway is located at a site, that site's *uplink* bandwidth requirements should be increased by the following amounts as a function of total number MNIS VRC Gateway talkpaths at a site and the number of sites participating in a call.

Figure 25: Uplink Bandwidth at Site with VRC Gateway(s)



NOTICE: The above charts describing *uplink* and *downlink* bandwidth for the MNIS VRC Gateways assume there is one call monitoring application in the system.

Estimating MNIS Data Gateway Link Bandwidth Requirements

When a an MNIS Data Gateway is located at a site, that site's *uplink* and *downlink* bandwidth requirements should be increased based on the amount of anticipated traffic load generated by the data application(s) being used. When computing the anticipated traffic load, it is useful to estimate the size of the data message, in bytes, and if VPN tunneling is being used in the system increase the size of the message by an amount as indicated in the table below.

Tunnel Type	Site Link Bandwidth Impact
No Tunneling	+ 0 bytes per message
GRE Tunneling	+ 24 bytes per message
GRE w/IPsec AH[3]	+ 68 bytes per message
GRE w/IPsec ESP[4]	+ 81 bytes per message
GRE w/IPsec AH and ESP	+ 105 bytes per message
[3] IPsec AH Assumes use of Secure Hash Algorithm (SHA) Hash Message Authentication Code (HMAC)	
[4] IPsec ESP Assumes use of Triple-DES and Secure Hash Algorithm (SHA) Hash Message Authentication Code (HMAC)	

The resulting message size is then multiplied by an estimate of the number of messages per hour generated by the data application. Finally, the result is converted to bits per second by multiplying by 8 bits per byte and then dividing by 3600 seconds per hour.

Examples

Using the guidance provided above, several examples are provided herein. The assumptions used in these examples match the assumptions stated above except where noted to be different.

Example: A repeater site having 8 repeaters, no GPS revert repeaters, in a 5 site system, and using GRE tunneling.
Uplink : 1.2 Mbps (read directly from the chart)

Downlink : 0.463 Mbps (read directly from the table)

Example: A repeater site having 6 repeaters, 5 Enhanced GPS revert repeaters, in an 8 site system, and using GRE tunneling.
Uplink : 1.2 Mbps (read directly from the chart)

Downlink : 0.343 Mbps (read directly from the table)

Example: The system of example 2 with a System Advisor client present at the site.
Uplink : 1.2 Mbps (read directly from the chart) + 0.055 Mbps = 1.255 Mbps

Downlink : 0.343 Mbps (read directly from the table) + 0.055 Mbps = 0.398 Mbps

Example: The system of example 3 with GRE w/IPsec AH tunneling.
Uplink : [1.2 Mbps (read directly from the chart) + 0.055 Mbps] x 1.25 = 1.569 Mbps

Downlink : [0.343 Mbps (read directly from the table) + 0.055 Mbps] x 1.25 = 0.500 Mbps

Tunneling Impact on Link Bandwidth Requirements

The following are charts showing uplink bandwidth requirements for a 4 repeater site and a 8 repeater site, both having no data revert repeaters. The uplink bandwidth requirement is shown as the number of sites in the system varies. The uplink bandwidth requirement for each of the tunneling modes is also shown.

NOTICE: The typical ADSL links which is about 1.5 Mbps or better, can easily accommodate systems having either a large number of sites and a nominal amount of repeaters per site, or a nominal amount of sites and a large number of repeaters per site.

Figure 26: Uplink Bandwidth Requirements for a Four Repeater Site

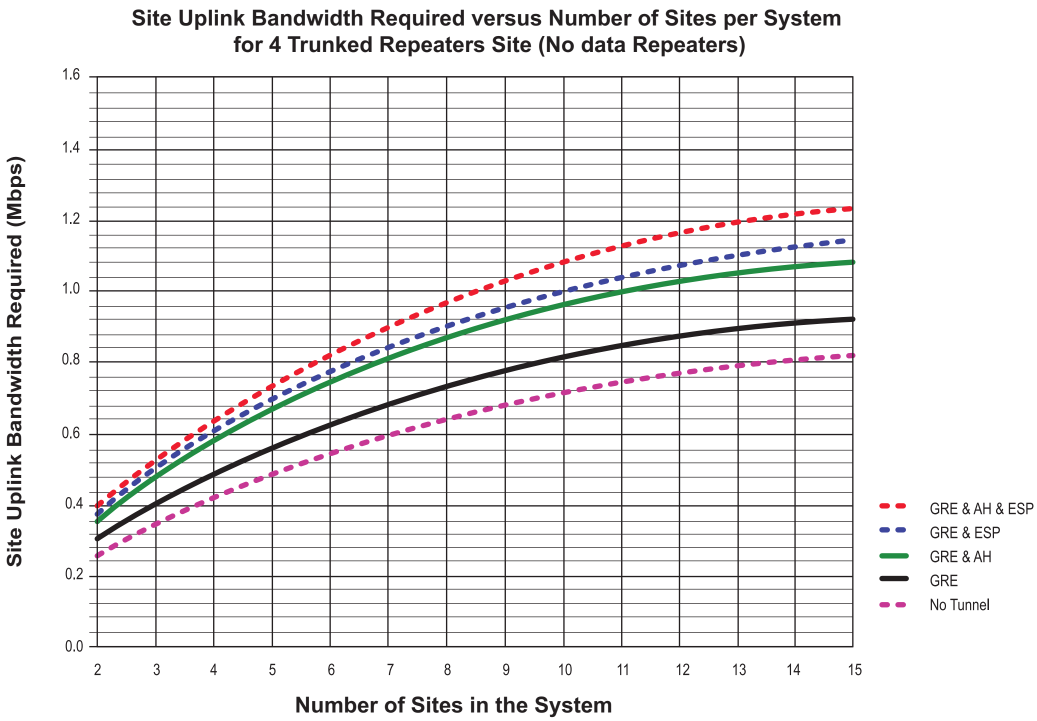
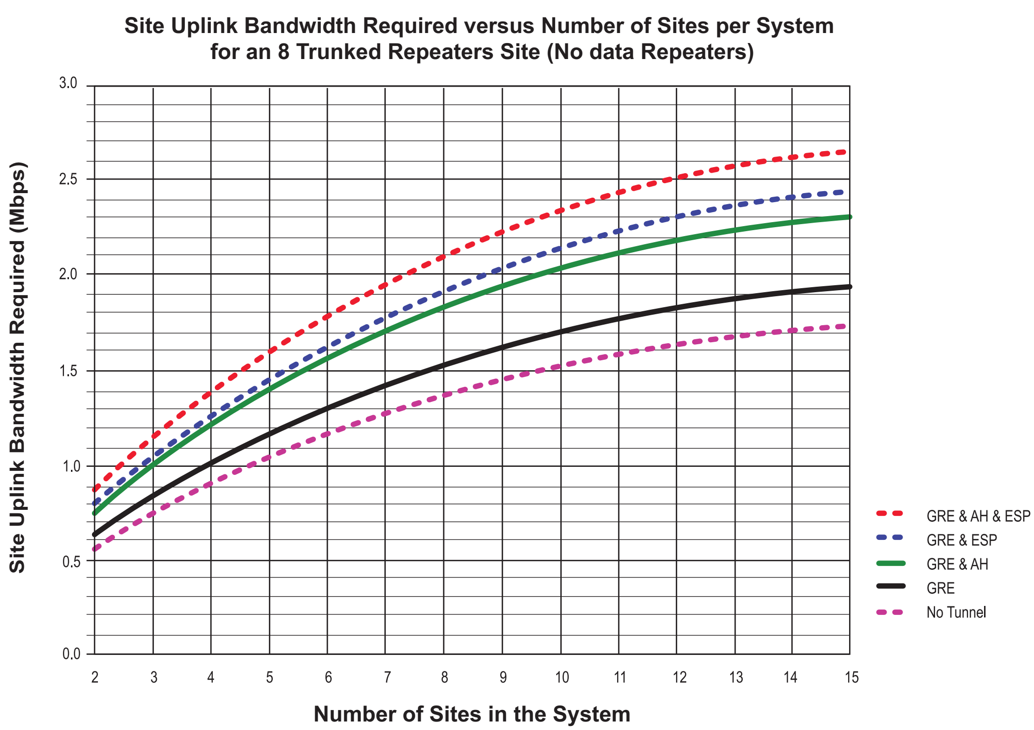


Figure 27: Uplink Bandwidth Requirements for an Eight Repeater Site



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Chapter 11

Frequencies Acquired from Frequency Coordinator

This chapter describes acquiring new frequencies from a frequency coordinator, converting existing frequency licenses, digital emission designators, and FCC Station Class and Service Class codes.

Acquisition of New Frequencies (Region Specific)

The licensing process varies from region to region. Generally, before the license process begins, detailed information about the proposed radio system must be provided to the frequency coordinator, such as:

Frequency/ Frequency Band
Frequency band or specific frequency it operates on.

Subscriber Radio Count
The number of radios that will operate on the system.

Output Power/ERP
The output power of the system amplifier, as well as the effective radiated power (ERP), which is the system's power at the antenna.

Emission Designators
Includes several pieces of vital information, such as modulation, signal, type of information and size of the channel. This determines the channel width your system will occupy. See Emission Designators in this section for more information.

International Coordination
For stations near another country's border, refer to a frequency coordinating committee for licensing frequencies adjacent to that country.

Antenna Information
You must also provide the following information about your antenna:

- **Structure**. the most common codes are:
  - B – Building with side mounted antenna
  - BANT – Building with antenna on top
  - MAST – Self supported structure
  - PIPE – Pipe antenna
  - POLE – Any type of pole antenna
  - TOWER – Free standing guyed structure used for communications purposes
  - Height
- **Antenna Height**. Antenna height from group to tip, in meters.
- **Support Structure Height**. If antenna is mounted on top of a building, it is the distance from ground to the top of the building. Check with the building management company for this information.

Coordinates
Latitude and longitude should be listed in degrees, minutes and seconds.

Site Elevation

The antenna site ground elevation above sea level. This information should always be in meters.

Conversion of Existing Licenses (Region Specific)

The process for converting existing licenses varies between regions and depends on the current licensing. Contact the local frequency coordinator’s office to inquire how to re-file existing frequency allocations.

There are also consultants that specialize in frequency coordination and can advise on the filing process. In the United States, this may include a new emission designator, a new station class code and/or a new radio service class code.

The following are general guidelines for frequency licenses:

Existing 12.5 kHz Licenses

An update must be filed as follows:

- Existing Analog licenses
  - New Emission Designator for all channels (see [topic title:] “Digital Emission Designator”)
  - Conventional
    - New Radio Service Code for all channels (see [topic title:] “Station Class and Radio Service Codes”)
    - New Station Class for all control channel capable channels (see [topic title:] “Station Class and Radio Service Codes”)
  - Decentralized Trunking (that is, LTR or PassPort)
    - New Station Class for all control channel capable channels (see [topic title:] “Station Class and Radio Service Codes”)
  - Centralized Trunking (that is, MPT1327 or SmartNet)
    - New Station Class only if adding more control channel capable channels (see [topic title:] “Station Class and Radio Service Codes”)
- Existing MOTORBO licenses
  - Conventional
    - New Radio Service Code (see [topic title:] “Station Class and Radio Service Codes”)
    - New Station Class (see [topic title:] “Station Class and Radio Service Codes”)
  - Decentralized Trunking (that is, Capacity Plus or Linked Capacity Plus)
    - New Station Class for all control channel capable channels (see Station Class and Radio Service Codes section)
  - Centralized Trunking (Connect Plus)
    - New Station Class only if adding more control channel capable channels (see Station Class and Radio Service Codes section)

Existing 25 kHz Licenses

An update must be filed as guided in the “Existing 12.5 kHz Licenses” list with the following caveats. Typically, the user is allowed to transmit a 12.5 kHz signal bandwidth at the same center frequency as the original 25 kHz license. It is not a straightforward process to convert an existing 25 kHz license into a pair of 12.5 kHz channels. Users are not allowed to split their 25 kHz channel into two 12.5 kHz sub-channels that would operate off center from the original license and adjacent to one another.

Digital Emission Designator

The following emission designators can be used for Capacity Max repeaters and subscribers. The preferred values should be used unless the old values where already issued for the channel.

The following designators can be used for repeaters:

- **Data only:** 7K60F7D (preferred) or 7K60FXD (old)
  - Data Revert Channels
- **Voice only:** 7K60F7E (preferred) or 7K60FXE (old)
  - Traffic channels on system not supporting any data applications
- Voice and Data: 7K60F7W (preferred) or 7K60FXE (old)
  - Control channel capable channels
  - Traffic channels on system supporting data applications

If it is likely that the purpose of the channel could change over time, file all channels with a Voice and Data emission designator.

The following designators can be used for subscribers:

- **Data only:** 7K60F1D (preferred) or 7K60FXD (old)
  - Data Revert Channels
- **Voice only:** 7K60F1E (preferred) or 7K60FXE (old)
  - Traffic channels on system not supporting any data applications
- Voice and Data: 7K60F1W (preferred) or 7K60FXE (old)
  - Control channel capable channels
  - Traffic channels on system supporting data applications

If it is likely that the purpose of the channel could change over time, file all channels with a Voice and Data emission designator.

The first four values are defined as the Necessary Bandwidth. This can be derived from the 99% Energy Rule as defined in Title 47CFR2.989. The next two values are the Modulation Type and the Signal Type. The final value is the Type of Information being sent. More information can be found with the region's frequency coordinating committee.

Station Class and Radio Service Codes

Based on the Federal Communications Commission (FCC) rules in the United States, trunking radio service can be on shared channels or exclusive channels. To determine the radio service code and station class code of license needed, consider the following:

- Radio Service Code
  - YG = Business/Industrial, Trunking
- Station Class Code
  - FB2 = Repeater on shared channel, internal systems
  - FB6 = Repeater on shared channel, for profit systems
  - FB8 = Repeater on exclusive channel

In the **800/900 MHz** bands, the channels are paired (uplink and downlink frequencies) and normally licensed for exclusive use.

In the **UHF** band, the channels are paired (uplink and downlink frequencies) and normally licensed for shared (non-exclusive) use. It requires additional coordination effort to find and license channels for exclusive use.

In the **VHF** band, the channels can be paired (uplink and downlink frequencies) or not paired (base/ mobile simplex frequency) – and are normally licensed for shared (non-exclusive) use. It requires additional coordination effort to find and license shared (non-exclusive) use repeater channels, and then the additional coordination effort to license repeater channels for exclusive use.

All channels that will be configured as capable of being utilized as a Capacity Max Control Channel must be exclusive use (FB8), but traffic channels can be either exclusive use (FB8) or shared (non-exclusive) use (FB2 or FB6). If the traffic channels or data revert channels are expected to have a high activity level, they should be exclusive use (FB8) as well.